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Controller Evaluation of Initial Data Link Air Traffic Control Services: Mini Study 2 Volume II

Nicholas J. Tolotta, et al.

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Final Report

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16. Abstract
This report details the results of Mini Study 2. This Mini Study was conducted at the Federal Aviation Administration (FAA) Technical Center utilizing the Data Link test bed. Initial Data Link air traffic control services were evaluated under part task simulation conditions in order to identify service delivery methods which optimize controller acceptance, performance, and workload.

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PREFACE

This report documents the second in a series of Federal Aviation Administration controller evaluations of en route air traffic control services planned for implementation on the Data Link system. The report is organized in two volumes.

Volume I contains the main body of the report. It includes a detailed description of the objectives of the study and of the technical approach and test methods that were used. In addition, the combined results of the study, conclusions, and recommendations are presented.

Volume II consists of a set of four appendixes to the report. These appendixes are referenced in Volume I and include documentation of the controller procedures used to deliver the test services as well as detailed analyses of the data that were collected.

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The planning and execution of the study were the results of cooperative efforts of several members of the Data Link Development Team. In particular, the following individuals played key roles in this research:

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION.

The Federal Aviation Administration (FAA) Test Plan for the Mode S Data Link defines a two-stage process for controller evaluation of candidate air traffic control (ATC) services. In the first stage, "mini" design studies are being conducted under controlled conditions which simulate only the essential components of controller tasks associated with the services. The goal of these studies is to identify service delivery methods which optimize controller acceptance, performance, and workload. In the second stage, full-scale simulation studies will be performed in order to verify the safety and efficiency of Data Link within the context of realistic operational scenarios. This report presents the results of the second FAA controller Mini Study of en route ATC services developed for implementation on the Data Link system.

OBJECTIVES.

The general purpose of this Mini Study was to extend the results obtained in Mini Study 1 and to evaluate the design of two functions which have been added to the initial package of en route ATC services. The specific objectives of the study were to: (1) define applications and controller procedures for the added free text and menu text services, (2) evaluate the refined altitude assignment and transfer of communication services as well as the text services under more complex test conditions than those employed in the Mini Study 1, and (3) provide a preliminary assessment of the impact of Data Link time delays, system degradation, and partial Data Link equipage of controlled aircraft.

DATA LINK OPERATION.

Data Link functions were integrated with the Host Computer System (HCS), operational software, and the Computer Display Channel (CDC) displays. Capabilities of the simulation system included radar data processing, tracking, and flight data inputs. Operational Data Link functions and procedures were integrated with current operational procedures and computer functions. Data base updates followed altitude clearances; handoffs between sectors included radio frequency assignments; and altimeter settings were automatically uplinked.

As dictated by the results of Mini Study 1, the Data Link transaction list display was located on the Plan View Display (PVD), the altitude assignment service was automatically uplinked following a data base update, and transfer of communication uplinks were manually controlled in order to dissociate this service from transfer of control. In all cases, the receipt of a downlinked pilot WILCO response automatically deleted associated list entries.

The two text services were developed as general Data Link functions applicable to a broad range of clearance and advisory messages. For this study, menu text permitted the controller to create a predetermined list of commonly used messages from which a desired clearance could be selected

and uplinked at any time. Free text gave the controller an option to compose and uplink a message in real-time. Text messages were limited to 20 characters.

APPROACH.

Nine full-performance level air traffic controllers from the Dallas/Fort Worth TRACON and the Fort Worth Center participated as subjects and observers in a series of ATC scenarios presented at the work stations in the FAA Technical Center Data Link test bed. The basic test scenario employed fixes and boundaries from the Universal Data Set (UDS) adaptation to create two routes carrying air traffic between two airports. Each route traversed two low altitude departure/arrival sectors adjacent to the airports, and two high altitude sectors located between the low altitude sectors. A total of 24 aircraft traveled through each sector during a 30-minute test run. Variations on the basic scenario were developed to reduce learning effects and to test the impact of partial Data Link equipage. These variations included the introduction of conflicting overflight traffic, an increase in air traffic density, and a reduction from 100 percent to 20 percent Data Link equipage of the aircraft in the test scenario.

The scenarios were used in a series of test runs designed to review and critique the text service designs and to evaluate the impact of making different combinations of the Data Link services available to controllers. Additional variables tested included the duration for display of confirmatory messages from the pilot, the impact of Data Link system failures in 10 percent of the attempted uplinks, and mixed Data Link equipage in the aircraft fleet. Both projective and actual workload ratings were taken after selected test runs using the Subjective Workload Assessment Technique (SWAT). Preference/acceptability judgments also were solicited from the controllers for each of the Data Link services as implemented for this study. Additional data collection which occurred during debriefing sessions included structured discussions to elaborate on the results obtained in the laboratory, and the completion of a wrap-up questionnaire designed to assess the adequacy of the test scenarios and the operational value of the tested services.

PRIMARY RESULTS.

General controller opinions continued to provide strong positive support for the initial package of en route Data Link services. Working with more realistic ATC problems than those presented in Mini Study 1, the subject controllers concurred that the implementation of appropriately configured versions of the four services will significantly reduce voice frequency congestion while increasing system capacity, safety, and efficiency. Although these projections will require confirmation in operational evaluation research using more complex scenarios and greater air traffic densities, rated workload was unaffected in this study by the substitution of Data Link procedures for current voice procedures. Furthermore, controller workload was not significantly affected by Data Link delays attributable to antenna rotation lag, a 10 percent rate of uplink failures, or a test environment in which only a fraction of the aircraft were Data Link equipped.

The conclusions of Mini Study 1 were upheld by the present results. The subjects continued to prefer the use of centralized PVD displays of Data Link transaction status, the use of Data Link without redundant voice communication, the necessity for downlinked pilot confirmation, and the use of automatic uplinks, where feasible, to minimize data entries. However, the current test conditions also presented situations which led the controllers to suggest several refinements to the services. In particular, subjects indicated that transfer of communication must be modified so that uplink authority transfers with the assignment of a new radio frequency, and that altitude assignment should permit the controller to selectively inhibit uplinks. Results for the text services showed that the controllers preferred to use menu text for control clearances and that it must, therefore, be designed to permit automatic system updates when needed. Free text was preferred as a back up for radio failures and as a method for transmitting advisories and other non-control messages.

Two issues which emerged during Mini Study 1 surfaced under the present testing conditions. The first of these is a requirement to develop Full Data Block (FDB) displays for Data Link transactions in order to reduce the display scanning demands of monitoring Data Link transactions. The second is the need to develop a method for permitting flexible control over uplinks, NAS updates, and FDB updates. This is due to the fact that ATC practices in different en route centers require that it be possible to selectively control these events for each transaction.

RECOMMENDATIONS.

Based on the results outlined above, several modifications to the design of the four tested services are recommended prior to full-scale, operational evaluation research. Briefly, a high priority should be assigned to the development of FDB displays of key transaction states for Data Link services. These displays should be easily interpretable and should supplement the transaction status list. Equally high priority should be devoted to the development of flexible control over the destinations of keyboard and trackball data entries for control clearances delivered by Data Link.

In addition, it is recommended that provision be made for linking menu text services to the remainder of the ATC system so that control clearance menu text uplinks can selectively update NAS, the FDB, or both. Transfer of communication and altitude assignment also should be modified in accordance with the present results in order to make these services compatible with the full range of ATC procedures employed in current field environments.

Finally, in order to identify any remaining limitations in the modified service designs, it is recommended that emphasis be given to the development of more complex ATC scenarios for the operational evaluation, and that this research reexamine the potential impact of Data Link failures, transmission delays, and partial equipage environments.

APPENDIX A

ANALYSIS OF GROUP DISCUSSIONS AND DEBRIEFING DATA

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The analysis reported here discusses the commentary offered in group discussion sessions with the participating Air Traffic Control Specialists (ATCS's) and in written responses to a related set of discussion guide forms that were handed out prior to the sessions.

Nine of the ten ATCS's who participated in Mini Study 1 also participated in Mini Study 2. The team was comprised of highly experienced (average of 15.7 years), full performance level controllers from the Fort Worth Center (eight ATCS's) and Dallas Fort Worth Terminal (one ATC). As in Mini Study 1, eight of the nine ATCS's operated the control positions in the test bed and one acted as a roving observer during the tests.

Quantitative ratings of workload impact and preferred service designs were taken during the tests as the controllers operated a traffic scenario using different mixes of voice and Data Link communications. The study's debriefing protocol sampled qualitative comments and opinion data on the Data Link services three times.

The first debriefing discussion focused exclusively on the displays, inputs, and procedures associated with the two new services that were introduced in the test bed simulation for Mini Study 2: menu and free text. This discussion followed a test bed exercise of the menu and free text services in a simplified traffic scenario. The second discussion addressed operational issues associated with four initial services: altitude assignment, transfer of communication (TOC), menu text, and free text. This discussion followed a series of test bed exercises which integrated the services with a more complex traffic scenario, more realistic system response times for Data Link transactions, and randomly occurring failures in Data Link message delivery. The third discussion focused on presentation of Data Link equipage and transaction status information in the full data block. This discussion reviewed and solicited feedback on the display concepts that will be incorporated in the test bed in future controller evaluation.

Results from all three data collection sessions were first examined together to identify generic themes and principles contained in the comments and to draw comparisons with the results obtained in Mini Study 1. Next, the results from each of the discussion sessions were reviewed separately. The following is an analysis of the Mini Study 2 group discussions and debriefing data.

GENERAL PRINCIPLES FOR DATA LINK COMMUNICATION

An analysis of controller comments from Mini Study 1 established a tentative set of basic operational and design principles for Data Link communication. This discussion uses those principles as a springboard for an account of the Mini Study 2 commentary. Generally, the themes and opinions expressed by the controllers in Mini Study 2 can be interpreted as evidence that substantiates and caveats the previously established principles. However, some new principles also emerged from the Mini Study 2 discussions.

A MESSAGE NOT ACKNOWLEDGED IS A MESSAGE NOT SENT.

Consistent with the established operating procedures for radio telephone communication, it was recommended in Mini Study 1 that a pilot response should be required to complete a Data Link transaction. While the Mini Study 2 comments continued to support the requirement for a pilot acknowledgement of Data Link communications, the controller's role in ensuring receipt of that acknowledgement became an area of controversy taken up in the discussions.

Although a final verdict was not reached on this issue, the process of thinking it through identified another interlocking issue to be considered in the choices. Since the arguments on both sides of the issue have something important to offer in reaching a final judgement, it was noted in the discussions that an incremental transition strategy may be the mechanism for meshing the merits of both perspectives. Initially, the controller would retain full responsibility for monitoring the Data Link communication process. As controllers (and pilots) gain confidence and experience with the new capabilities and procedures, more of the communication management tasks could be delegated to the ground computer (and the avionics) (see reference 1).

USE RADIO TELEPHONE AS THE PRIMARY COMMUNICATION MODE TO RELAY TIME-CRITICAL MESSAGES AND TO RESOLVE EXCEPTIONS TO DATA LINK COMMUNICATION.

In Mini Study 1, the consensus among the controllers was that voice communication offered an operational advantage for delivery of all time-critical control instructions. Voice was also seen as the preferred mode for handling situations where a controller fails to receive timely acknowledgement of a Data Link instruction.

Controller discussion in Mini Study 2 generally reinforced the same delimitation of functions and priorities for the Radio Telephone and Data Link communication modes. However, the written responses suggest a preference for the Data Link mode. Evidence from Mini Study 2 suggests that full Data Link communication may impose a heavy visual monitoring load on the controller. Using a mixed mode approach to handle exceptions and compensate for transmission delays may help distribute some of the added visual monitoring load.

DISPLAY DATA LINK TRANSACTION STATUS IN THE FULL DATA BLOCK (FDB).

Silent Data Link communication between controllers and pilots warrants feedback on the progress of each transaction. To minimize the display scanning required to track the status of a transaction, it was recommended in Mini Study 1 that status indicators be encoded in the FDB. The abbreviated FDB display of Data Link transaction status would be supplemented by a list display that logs all sector transactions.

The Mini Study 2 commentary provided ample evidence supporting this principle. It was mentioned in all of the group discussions and reported as a desired test bed enhancement on discussion guide forms. In fact, the Mini Study 2 test bed experience with an increased traffic sample and a corresponding longer Data Link status list appeared to further consolidate controller opinion and reinforce the requirement for a display of Data Link transaction status that is better integrated with the traffic situation display and, therefore, easier to monitor. As things stand, data block displays appear to be the most promising approach for condensing and integrating the additional visual display information inherent in Data Link communication.

PROVIDE PROACTIVE MANAGEMENT OF DATA LINK TRANSACTIONS BUT MINIMIZE CONTROLLER INPUTS.

Just as the controller uses a set of controls to manage the voice communications system, a comparable set of capabilities must be devised to assist the controller in (1) sending, (2) generating, and (3) receiving Data Link communications. Aggregating comments over the two studies yielded some specific capabilities needed to assist the controller and also achieve the desired balance between positive control over Data Link transactions and minimal keyboard entries.

1. To effectively manage sending of Data Link messages, controllers in Mini Study 1 requested the flexibility to select and deselect an automatic message uplink by position, service, or message. In addition to providing for a default selection, the controllers also suggested an override feature to handle exceptions. Because only partial progress toward implementation of these capabilities was realized in Mini Study 2 (different defaults were implemented for each of the services, but they were not controller-selectable). A requirement for these same capabilities was reiterated in the Mini Study 2 discussions.

2. To minimize controller inputs for message generation, it was recommended that existing Air Traffic Control (ATC) system information be made available for Data Link messages. Use of current controller inputs for related ATC functions and information derived from automatic system events (sector boundary crossing) were two initial assumptions made for Data Link message generation. In Mini Study 1, the controllers extended this logic by recommending implementation of a menu text service, which is actually a message generation aid rather than a true Data Link service. In Mini Study 2, the discussions on menu text continued to develop the same principle. It was recommended that templates be used to preformat menu messages and reduce the controller-entered portion of the message.

3. To minimize Data Link inputs related to receipt of Data Link message, automatic clearing of status displays for completed (WILCOed) transactions was also recommended in Mini Study 1. In Mini Study 2, the controllers began to discuss the prospect of delegating message receipt tasking to the computer and capabilities for automatic transfer of Data Link information to update other ATC subsystems.

COUPLE RESPONSIBILITY FOR RADIO TELEPHONE COMMUNICATION WITH RESPONSIBILITY FOR DATA LINK COMMUNICATION.

To enhance operational effectiveness and simplify the exchange of information when transferring responsibility for air-ground communication from sector to sector, the procedure should direct that completion of the transfer of communication exchange should also authorize Data Link communication. Inclusion of the "/OK" override suffix would be required for uplink of a Data Link message by any other sector controller.

AVOID CONTROLLER REENTRY OF COMPLETED DATA LINK TRANSACTIONS TO UPDATE THE OTHER ATC SYSTEM COMPONENTS.

As was mentioned earlier, the Mini Study 2 discussions emphasized the operational need to transfer data from a Data Link display to update other ATC displays (data blocks) and the National Airspace System (NAS) data base. The most common theme in the Mini Study 2 discussions had to do with incorporation of NAS message types in the menu build sequence to allow automatic processing of updates associated with completed menu text Data Link transactions.

Future evaluations should take up the message sending side of the issue. So far, with the exception of the en route minimum safe altitude service, only controller initiated Data Link transactions have been examined. Pilot initiated transactions and maneuver advisories generated by ATC automation functions constitute other potential inputs to Data Link message sending and generation functions.

CRITIQUE OF MENU AND FREE TEXT SERVICES

To a large extent, the principles of Data Link communication presented in the preceding section establish a general framework for understanding the detailed data on the individual services. This section is devoted to an extended analysis of the two services introduced in Mini Study 2: menu text and free text. The text services from Mini Study 2 constitute controller aids for Data Link message generation. For this reason, the text services can be considered part of a larger class of Data Link communication management functions, and much of the commentary concerned merging communications with the surrounding ATC system functions.

MENU TEXT.

Not surprisingly, there was unanimous agreement among the controllers that menu text provides a very useful Data Link capability (see table A-1). Nonetheless, there were also some negative reactions to the service as

TABLE A-1. DATA LINK MINI STUDY 2 DISCUSSION OF MENU AND FREE TEXT

Written Responses to Discussion Guide Form

MENU TEXT

1. Do you feel that menu text provides useful controller capability?

_9_ very useful ___ somewhat useful ___ not useful

2. Can you thank of any way to redefine the service that would make it more useful?

- *Add NAS message types*
- *Add FDB update*
- *Highlight selected entry: menu and status lists*
- *Automatic uplink of routine instruction on boundary crossing*
- *Do not link data link communication responsibility with handoff*
- *Provide fill-in phrases for menu text*

3. Would you be able to use the test displays, inputs, and procedures in an operational environment?

_4_ Yes ___ No

_5_ Yes, with reservations:
- *Monitoring list is distracting*
- *Message content field does not identify message*
- *Eliminate "sent", "delivered" statuses*

4. How logical was the flow of information between the pilot and the controller in relation to the tasks you performed?

_9_ Logical ___ Somewhat illogical ___ illogical

5. Was the terminology and phraseology presented in the test displays understandable?

_8_ Always: ● *Need to standardize abbreviations*
_1_ Sometimes: ● *6 character abbreviations difficult to interpert*
___ Never

6. Was the content of the displayed information complete?

_4_ Complete _3_ Incomplete: ● *Message content field not large enough to identify message*
_1_ Too much information : ● *too many statuses*

7. Was the content of the displayed information appropriate?

_8_ Appropriate: ● *Except message content field*
_1_ Inappropriate: ● *Message content field too small*

8. Were the inputs required to build a menu message suitable for an operational environment?

_8_ Yes
_1_ Yes, With reservations: ● *Current keyboard doesn't contain correct symbol keys*
___ No, Because

9. Were the inputs required to uplink a menu message suitable for an operational environment?

_7_ Yes
_2_ Yes, With reservations: ● *Should have FDB display and NAS updates with menu message*
___ No, Because

10. During the test session, did you encounter any situations where where there was a potential for miscommunication?

_3_ No
_6_ Yes, Describe the situation and what you did:
- *Accidently selected wrong menu item and had problems verifying selection from message content display in status list.*
- *Since data link eligibility was linked to handoff NOTTOC, it was impossible to send message after handoff but this in essential.*

11. During the test session, did you find a need for voice commuication

_6_ No ● *But voice would be needed in heavy traffic which demands immediate response*
_3_ Yes ● *Clarificationof data link communication*
- *Issue speed change after handoff*
- *Imminent situations*
- *Vectors, speed control, multiple altitude changes*

12. In your opinion how would the availability of menu text affect current procedures?

- *Would reduce radio congestion and off load routine messages (5)*
- *Would reduce controller workload (3)*

● **Write in comments**

TABLE A-1. DATA LINK MINI STUDY 2 DISCUSSION OF MENU AND FREE TEXT (Continued)

Written Responses to Discussion Guide Form

FREE TEXT

13. Do you feel that free text provides a useful controller capability?

8 Very useful
___ Not useful
1 Somewhat useful:
- *Need ability to store free text*

14. Can you think of any way to redefine free text that would make it more useful?

- *Expand message size (4)*
- *Store non-control information for automatic uplink based on boundary corssing, flight level and destination*
- *Provide storage and retrieval of free text*
- *Allow uplink of route amendment*

15. During the test session, how did you use free text?

- *Wx-icing, chop*
- *Non-control information*
- *Hold instructions*
- *Speed, heading changes*
- *Interim altitude*

16. Would you be able to use the test displays, inputs, and procedures in an operational environment?

5 Yes
4 Yes, With reservations:
- *Need more characters*
- *Need sigmet service*

___ No, Because

17. Was the message size adequate for use in an operational environment?

3 Yes
3 Yes, With reservations:
- *Larger size would be better*

3 No, Message size should be increased to:
- *Unlimited*
- *200 + characters*

18. What do you feel would be the best way to present a free text downlink to the controller?

- *D-CRD with alert on the R-side*
- *Free text downlink should not be received by the controller*
- *R-CRD*

19. In your opinion how would the availability of data link as a back-up affect current (No-Comm) procedures?

- *Could minimize/eliminate "No-Comm" procedures (5)*
- *Helps in comm failure; but very useful where pilot is on wrong frequency*
- *Data link is a welcome back-up*
- *Could save time in descent phase by helping to detect comm problem early*

- **Write in comments**

currently defined and implemented. The two most common critical themes in the discussion data on menu text had to do with integrating Data Link menu transactions with ATC display and data base updates and display of menu message content information in the Data Link status list.

FREE TEXT.

Originally conceived as a back-up for radio telephone communication failures, the free text service was designed to allow the controller to compose and uplink "free form" messages. In the test bed implementation of the free text service, these messages were not preserved for later retrieval. Moreover, the initial implementation restricted message size to 20 characters.

Most of the controllers felt that free text would provide a useful Data Link capability (see table A-1). At the same time, most felt that message size would have to be expanded.

Free text was difficult to evaluate in a test environment. By definition, it is not expected to be used frequently, thus representative ATC situations are difficult to include in a test scenario. Furthermore, except for an initial exchange to advise the controller and pilot of the radio telephone failure, it would seem that from the controller's perspective most subsequent communications could be accomplished by using other Data Link services.

When asked how the availability of Data Link as a back-up communication link would affect procedures, most controllers felt that there would be a significant benefit. For the rare situation where an equipped aircraft experiences a radio failure, Data Link would eliminate the need for "no-comm" procedures. Procedures that apparently are not well understood by controllers or pilots.

For the more typical situation where the aircraft is actually tuned to the wrong frequency, a Data Link communication system could indicate which sector last assumed communication responsibility for the flight.

DATA LINK SERVICE DEFINITIONS AND PROCEDURES

This part of the evaluation followed a series of laboratory exercises designed to assess cumulative impact of Data Link services and impacts of system response time and reliability on ATC operations.

DATA LINK FUNCTIONALITY.

Overall, controller assessments of the initial services were favorable. The summary interpretation of the discussion data is that, taken together, the services provide sufficient Data Link communication capability to accommodate the en route situations.

With one exception, there was general agreement that all of the services were appropriate applications for Data Link (see table A-2). As an exception, one of the controllers remarked that the free text service would not be suitable for delivery of control instructions, primarily owing to the lack of any input error checking.

DISPLAYS, INPUTS, AND PROCEDURES.

A majority of the controllers felt that the test bed displays, inputs, and procedures would be usable in an operational environment provided that some modifications were made. The most common problems cited were those previously discussed in the critique of menu text: the lack of NAS updates for menu messages and the ambiguity in the message content field due to the current procedure used for list display generation (display of first six characters). Some of the controller remarks here also dealt with display clutter caused by presentation of intermediate transaction status indications.

Reactions were mixed on the difficulty of monitoring the status of Data Link transactions. The extra visual task load associated with a silent communication process, the added display scanning required by a (spatially) separate transaction status list display, and competition between the primary traffic situation monitoring and Data Link list monitoring were noted.

DELAYS AND DELIVERY FAILURES.

Regarding two critical issues simulated in the Mini Study, transmission delays and message delivery failures, the available evidence suggests that neither delays nor failures present insurmountable obstacles to achieving an operationally acceptable Data Link communication capability.

Generally, the controllers felt that the delays associated with a Data Link transaction would have a minor effect or no effect on their current work methods. However, only a portion of the expected system response time for a Data Link transaction was simulated, the transmission delay associated with antenna rotation. The pilot response time component of system response time was not represented realistically. The simulation pilots tended to respond immediately to an uplink; other research (see reference 2) reports pilot response times averaging about 10 seconds. In the discussion of delays, some controllers commented that Data Link communication would likely encourage a more anticipatory approach to ATC, which is entirely consistent with the positive ATC philosophy espoused in the controller handbooks, FAA Orders 7110.65 and 7220.2 (see references 3 and 4).

Surprisingly, most of the controllers also felt that message delivery failures had no effect or only a minor effect on their work methods. In fact, one commented that the response time associated with a failure status display was quicker than that associated with a WILCO, so that even when it was necessary to reissue the instruction, minimal delay was added to the total (uplink/downlink) transaction time.

TABLE A-2. DEBRIEFING DISCUSSION OF SERVICE DEFINITIONS AND PROCEDURES

Written Responses to Discussion Guide Forms

FUNCTIONALITY

1. Based on the tasks you were able to perform, do any of the service appear to be inappropriate?

_8_ *No* _1_ *Free text:*

- *Not appropriate for control instructions, no error checking is possible*

2. Did you use free text during the test session?

___ *No* _8_ *Yes, Used free text to:*

- *Handle lost communication*
- *Heading, speed changes*
- *Holding instructions*
- *Chop information*
- *Traffic advisories*
- *Expedite rate of descent*

(1) No response

3. Based on your test experience with all services, are the proposed limits on eligible menu messages acceptable?

_8_ *Acceptable:*

- *Assuming that menu text is modified to include NAS message types*

(1) No response

DISPLAYS, INPUTS, AND PROCEDURES

4. Would you be able to use the test displays, inputs, and procedures in an operational environment?

_2_ *Yes*

_6_ *Yes, With reservations:*

- *Message content field should present value of altitude or speed assignment*
- *Menu text should generate FDB and data base updates*
- *Monitoring list will be unmanageable in heavy traffic*
- *Streamline list: No "sent" or "delivered" status*

___ *No, Because*

(1) No response

5. When all services were operating, how easy was it to monitor the status of data link transactions?

_5_ *Easy:*

- *Because of low traffic count*
- *Visual scan was increased*

_4_ *Somewhat difficult:*

- *Too much scanning*
- *Add FDB displays*

___ *Very difficult*

6. Was the terminology and phraseology presented in the test displays understandable?

_6_ *Always*

_3_ *Sometimes:*

- *Truncation of message content made it difficult to identify message*
- *Free text should use standard abbreviations*

7. During the test, did the services operate as expected?

_9_ *Yes*

___ *No*

- **Write in comments**

TABLE A-2. DEBRIEFING DISCUSSION OF SERVICE DEFINITIONS AND PROCEDURES (Continued)

Written Responses to Discussion Guide Forms

DELAYS AND DELIVERY FAILURES

8. Did delays associated with a data link transaction affect your work methods?

_3_ *No effect* ___ *Yes, Major effect*
_6_ *Yes, Minor effect:*
- *Data link will encourage more anticipation to allow adequate lead time*
- *Major effect likely with more traffic*

9. Did the message delivery failures affect your work methods?

_7_ *No*
- *In fact "NAK" was quicker than "WILCO" response*

_2_ *Yes, Minor effect*
- *Had to repeat same message*

___ *Yes, Major effect*

10. How did you handle message delivery failures during test?

_2_ *Use radio to deliver the message*
_4_ *Resent the data link message*
_3_ *Sometimes used radio; sometimes resent data message:*
- *Depends on promptness of reply needed from pilot*

MISCOMMUNICATION

11. During the test, did you encounter any situations where there was a potential FNC miscommunication?

_4_ *No*
_4_ *Yes, Describe the situation and what you did:*
- *List update caused uplink of incorrect entry - push-up moved trackball selection*

(1) No response

ROLE OF VOICE COMMUNICATION

12. During the test, did you find a need for voice communication?

_4_ *No*
_3_ *Yes, Describe the role of voice communication*
- *Used voice to communicate after handoff*
- *Used voice for messages not included in data link services*
- *Used voice for data link delivery failures*
- *Used voice to confirm instructions when data link response was too slow*

(2) No response

ADDITIONAL CAPABILITIES

13. In terms of managing the data link displays and transactions, are there any other capabilities that would make data link more useful?

- *Display data link status in FDB (3)*
- *Data link and radio communication should be transferred at the same time*
- *Too many different statuses to be monitored*
- *Expand free text message size*
- *Downlink of position and intent information*

TWO-PERSON SECTOR OPERATION

14. What do you feel is the appropriate role of the D-controller in data link communication?

- *Act as a second R controller -- 1 handles voice, 1 handles data link*
- *Assist the R controller -- D handles free text, non-control information, and evaluates downlinks, D handles data link exceptions*

- **Write in comments**

MISCOMMUNICATION.

When asked about the potential for miscommunication with Data Link, reactions were mixed. Among those who felt that they there was potential for miscommunication, perhaps the most serious problem cited had to do with trackball selection of status list entries for uplink. It was reported that automatic list updates, which move the entries up or down, could cause the controller to inadvertently select and uplink the wrong message. While this is an intractable problem associated with any form of dynamic list, better feedback on the selected entry (highlighting) may help. Better feedback on message selection may also help remedy another miscommunication problem that was cited, entry of an incorrect menu message identifier. If the selected menu item was highlighted in the list after the identifier was entered, the additional feedback might help the controller detect the error before uplink.

ROLE OF VOICE COMMUNICATION.

Voice was also used to handle Data Link message delivery failures and to confirm Data Link transactions when the Data Link acknowledgement was determined by the controller to be too slow.

ADDITIONAL CAPABILITIES.

It is sufficient to state that the controllers felt that implementation of an FDB display would ameliorate much of the added workload of monitoring Data Link transaction status. Other recommendations included test bed refinements to couple radio telephone and Data Link communication responsibility and to suppress the display of normal status indications in the Data Link list.

TWO-PERSON SECTOR OPERATIONS.

The final topic taken up in the debriefing was the role of the Data (D) controller in Data Link communication. The comments generally describe two sorts of roles: a radar controller assistant and a co-controller role. The radar assistant role closely resembles today's breakdown of responsibilities. The D position essentially has a redundant set of Data Link capabilities but the D controller performs support functions--list monitoring, relay of non-control information--or primary functions at the R-controller's request, follows-up on Data Link exceptions. The cocontroller role was characterized more as a second R-controller who handled either Data Link or radio telephone communication in addition to the duties now performed by the handoff controller when that position is staffed.

DATA BLOCK DISPLAYS

This final section reviews the latest thinking on data block displays as reported in the group discussion of proposed display concepts. Two kinds of information displays were discussed: Data Link equipage and Data Link transactions status. The analysis examines each in turn.

DATA LINK EQUIPAGE.

Information on Data Link equipage will appear in the flight strip and the FDB. The flight strip information is filed with the flight plan to indicate the active avionics for the flight; the data block display is based on the flight strip information. Air-ground communication keeps the information current.

The controllers recommended that Data Link equipage be incorporated into the aircraft type portion of the aircraft data field. The proposal for the FDB display was to add a prefix to the call sign. This display will be updated when the information in the aircraft type field is updated. More discussion and analysis will be needed to determine whether another, more dynamic display indication of channel availability is needed to present feedback from automatic monitoring of the communication network.

DATA LINK TRANSACTION STATUS.

The precise number of transaction states indicators remain an open issue. As an upper limit, five status indicators remain under consideration: (1) HELD (awaiting manual uplink), (2) SENT (uplinked), (3) DELIVERED (technical acknowledge), (4) WILCO (affirmative pilot reply), and (5) FAILED (no technical acknowledgement, UNABLE pilot reply, or message timed out with no pilot reply). How many of these get displayed depends on where the line between controller and computer responsibility is drawn.

In one sense, the issue of statuses cannot be resolved until a transition strategy is defined. As of now, this has not occurred. The logic of the FAA Data Link program foresees an incremental process of increasing computer responsibility for communication functions. How soon each succeeding automation step is taken depends partly on the priorities decided upon by the people who will be assuming responsibility for the nonautomated procedures.

Ignoring the controversy about the proper set of statuses for now, the opinions on data block displays tended to be positive and the potential workload benefits of the FDB display approach were viewed as highly significant.

There were some suggestions and criticisms regarding the proposed display symbology and logic. In terms of symbology, it was suggested that brightness coding be employed. The reasoning was that it would take less mental effort to detect, interpret, and make a decision about a transaction if status changes were depicted as changes in display brightness.

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APPENDIX B

ANALYSIS OF CONTROLLER WORKLOAD, PREFERENCE, AND COMMUNICATION DATA

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

Data collection activities for this study were divided into two major parts. In Part One, the subjects were introduced to candidate versions of the Free Text and Menu Text services during informal simulation runs using the basic ATC scenario without overflights. The primary goal of these informal runs was to provide a basis for an initial controller review and critique of the services. A secondary objective of Part One was to identify an appropriate duration for the display of confirmatory pilot responses to Data Link messages. Accordingly, each controller completed a test run with an immediate deletion of the transaction display after the pilot WILCO was received, and a second run in which the WILCO response display persisted for 12 seconds after the response was received.

Part Two of the study consisted of five formal data collection runs designed to assess the effects of the number and type of Data Link services available to the controller, and the impact of failed technical acknowledgements and partial equipage. In these runs, more complex versions of the test scenario were used which included conflicting overflights and, in one case, increased en route traffic.

The primary criteria for evaluating the effects of display persistence in Part One and the impact of all variables in Part Two were controller ratings of workload and preference provided after the completion of selected simulation runs.

WORKLOAD MEASURES.

Controller workload was assessed in this study using two versions of a subjective rating method known as the Subjective Workload Assessment Technique (SWAT). SWAT was developed in the early 1980's by U.S. Air Force researchers in order to provide a standard rating method which results in quantitative, interval level estimates of operator workload in simulation and operational testing situations. In its original form, SWAT is used by subjects to make judgments about the level of workload directly experienced during the performance of an operational task. A second version of SWAT, known as the Projective Subjective Workload Assessment Technique (PROSWAT), is used by experienced operators to make projective estimates of the workload that would be produced in an operational situation under a specific set of test conditions. Thus, SWAT ratings represent the workload actually produced in a test session, while PROSWAT ratings permit the subject to extend his judgments to the full set of operational conditions with which he is familiar.

Both SWAT and PROSWAT ratings were used in Part Two of the present Mini Study to address different sets of experimental questions. SWAT ratings were solicited after each test run in order to assess the difficulty of the controller tasks presented in the simulation. Comparisons of the ratings in the different conditions were designed to determine the impact on subject workload of the following conditions:

1. The availability of two Data Link services (Altitude Assignment and Transfer of Communication) versus four services (Altitude Assignment, Transfer of Communication, Free Text, and Menu Text).

2. Introducing 10 percent failed technical acknowledgements (NAK's) to uplinks initiated by the controllers.

3. Reducing the number of aircraft equipped with Data Link.

PROSWAT ratings were obtained after two of the test runs in order to derive projected estimates of the workload that would be experienced by controllers when providing each of the four Data Link services under operational conditions. The purpose of the PROSWAT ratings was to obtain expert evaluations of the workload impact of each of the service implementations, independent of the simulation scenarios used in this study.

SWAT and PROSWAT utilize the same rating scale which requires subjects to judge workload as a combination of ratings on three, 3 point scales representing the dimensions of time load, mental effort load and psychological stress. The SWAT/PROSWAT scale is shown in figure B-1.

In order to generate quantitative data using this scale, subjects provide information on how time, effort, and stress combine to produce their individual concept of mental workload. This scale development exercise is accomplished prior to actual data collection by asking subjects to sort a set of 27 cards on which are printed all possible combinations of the descriptors on the time, effort, and stress scales. Subjects sort the cards to produce an ordering that represents situations ranging from low to high workload. The sorts are subjected to computerized conjoint analysis which determines the combinatory rule governing the sort. An iterative routine is then used to generate an interval scale value for each of the 27 combinations that fits the combinatory rule and preserves the original ordering. The result of this process is a look-up table for each subject or subject group that converts the discrete time, effort, and stress ratings to the unitary scale.

When the rating scales are used during data collection, the subjects make workload ratings of the test conditions by assigning a value of 1 (low) to 3 (high) on the time, effort, and stress scales. These ratings are then interpreted as a single value on the overall quantitative workload scale found in the look-up table.

Card sort data for the SWAT scale development in this study were derived from the sorts obtained from the subjects in the first Mini Study. Prior to the start of data collection, subjects were refamiliarized with the SWAT technique during a briefing. They were also provided with printed instructions for the use of the scale. These instructions, which also contain examples of the actual SWAT and PROSWAT rating forms used in the study, are presented in a separate section at the end of this appendix.

PREFERENCE MEASURES.

Ratings of controller preferences were used in this study to assess the perceived level of acceptance for specific service implementations and for the persistence of the WILCO display once a Data Link transaction had been completed. The preference scale required subjects to judge each service implementation or WILCO persistence time in terms of its effect on system

I. TIME LOAD

1. OFTEN SPARE TIME. INTERRUPTIONS, OR OVERLAP AMONG ACTIVITIES OCCUR INFREQUENTLY OR NOT AL ALL.

2. OCCASIONALLY HAVE SPARE TIME. INTERRUPTIONS, OR OVERLAP AMONG ACTIVITIES OCCUR FREQUENTLY.

3. ALMOST NEVER HAVE SPARE TIME. INTERRUPTIONS OR OVERLAP AMONG ACTIVITIES ARE VERY FREQUENT OR OCCUR ALL THE TIME.

II. MENTAL EFFORT LOAD

1. VERY LITTLE CONSCIOUS MENTAL EFFORT OR CONCENTRATION REQUIRED. ACTIVITY IS ALMOST AUTOMATIC. REQUIRING LITTLE OR NO ATTENTION.

2. MODERATE CONSCIOUS MENTAL EFFORT OR CONCENTRATION REQUIRED. COMPLEXITY OF ACTIVITY IS MODERATELY HIGH DUE TO UNCERTAINTY, UNPREDICTABILITY, OR UNFAMILIARITY. CONSIDERABLE ATTENTION IS REQUIRED.

3. EXTENSIVE MENTAL EFFORT AND CONCENTRATION ARE NECESSARY. VERY COMPLEX ACTIVITY REQUIRING TOTAL ATTENTION.

III. PSYCHOLOGICAL STRESS LOAD

1. LITTLE CONFUSION, RISK, FRUSTRATION, OR ANXIETY AND CAN EASILY BE ACCOMMODATED.

2. MODERATE STRESS DUE TO CONFUSION, FRUSTRATION, OR ANXIETY NOTICEABLY ADDS TO WORKLOAD. SIGNIFICANT COMPENSATION IS REQUIRED TO MAINTAIN ADEQUATE PERFORMANCE.

3. HIGH TO VERY INTENSE STRESS IS DUE TO CONFUSION, FRUSTRATION, OR ANXIETY. HIGH TO EXTREME DETERMINATION AND SELF-CONTROL REQUIRED.

FIGURE B-1. SWAT/PROSWAT SCALE

safety and efficiency. These test conditions could be judged either as acceptable or unacceptable. If judged acceptable, the condition was rated on a 7-point scale ranging from "highly preferred" to "acceptable, but not preferred." Instructions for use of this scale and an example of the rating form are included in the final section of this appendix.

DATA COLLECTION SUMMARY.

Table B-1 presents the data collection plan for each of the test conditions in the experimental design. The left column of the table lists each measurement instrument that was employed. A key to the numbered test conditions is presented below the table.

INTRODUCTION TO THE CONTROLLER WORKLOAD AND PREFERENCE RATING SCALES (SUBJECT INSTRUCTIONS).

BACKGROUND. As you know, the goal of this study is to obtain expert opinions from air traffic controllers about the most appropriate ways in which to implement ATC services using Data Link. When we start our simulations in the Data Link test bed you will be controlling air traffic in a series of scenarios. In order to evaluate the Data Link service designs, we will ask you to provide ratings after each test run. The purpose of this document is to refamiliarize you with the scales that you will be using to make the ratings, and to describe the ways in which we will use them.

PREFERENCE. Although we will be asking you for a wide variety of comments during this study, our primary quantitative data will be derived from your ratings on the scales mentioned above. Because the rating data will form the basis for a number of Data Link decisions, it is extremely important that we all agree on what we mean by each type of rating scale.

The first scale that you will complete after two of the test runs is the PREFERENCE/ACCEPTABILITY scale. The form that will be used for this scale is shown in figure B-2.

Note that the form actually requires you to make two decisions. First, for each of the services you will need to decide whether the implementation under test is acceptable or unacceptable. Second, if you have decided that it is acceptable, you will need to assign it a value on the 7-point scale that indicates the extent to which you prefer it. Thus, you would assign the service implementation a value of "1" if you found it to be both acceptable and highly preferable. If it were acceptable but not highly preferred, you would assign it a higher number according to the extent to which it is less preferable. However, if the implementation were completely unacceptable, you would not assign it any of the numbers, and instead mark the COMPLETELY UNACCEPTABLE blank on the form.

In making your decisions about acceptability and preference, your prime consideration should be the impact of a service implementation on the SAFETY and EFFICIENCY of controller performance. Once you have made your ratings, please remember to use the comments section to briefly explain the reasons for your ratings.

TABLE B-1. DATA COLLECTION PLAN

Metric	Test Case/Run 1	2	3	4	5	6
Overall SWAT	-	X	X	X	X	X
PROSWAT						
Alt Ass.	-	-	X	-	-	-
Trans Com.	-	-	X	-	-	-
Menu Text	-	-	-	X	-	-
Free Text	-	-	-	X	-	-
PREFERENCE						
Alt Ass.	-	-	X	-	-	-
Trans Com.	-	-	X	-	-	-
Menu Text	-	-	-	X	-	-
Free Text	-	-	-	X	-	-
WILCO Persistence	X	-	-	-	-	-

Key to Test Conditions

1: Part One, Informal Testing (WILCO persistence conditions).
2: Baseline, Current System (no Data Link).
3: Altitude Assignment and Transfer of Communication Data Link Services Only.
4: Altitude Assignment, Transfer of Communication, Menu Text, and Free Text Data Services (all services).
5: All Services, 10 Percent Failed Technical Acknowledgement on Uplink.
6: All Services, 10 Percent Failed Technical Acknowledgement and Partial Data Link Equipage on Controlled Aircraft.

SUBJECT ____________________ SERIES I / II

SECTOR __________ ACTIVE / PASSIVE

TEST OPTION ____________________

Rate the display / procedural test option that you have just examined according to how acceptable it would be to controllers involved in each of the three services. In rating the acceptability of this option, you should consider the way in which it would affect the SAFETY and EFFICIENCY of the controller's performance.

Place an "X" next to the number which best describes the acceptability of this option for each service. If this option is completely unacceptable, place an "X" in the box. Use the space below the scales to briefly explain your ratings.

	HIGHLY PREFERRED			MODERATELY PREFERRED			ACCEPTABLE BUT NOT PREFFERED	
	1	2	3	4	5	6	7	
ALT CONF	___	___	___	___	___	___	___	☐
TRAN COMM	___	___	___	___	___	___	___	☐
	___	___	___	___	___	___	___	☐ COMPLETELY UNACCEPTABLE

COMMENTS:

FIGURE B-2. PREFERENCE/ACCEPTABILITY SCALE

WORKLOAD. The second type of judgement that we will be asking for after the test runs will be one or two workload ratings. The scale that we will be using for the workload ratings is known as Subjective Workload Assessment Technique (SWAT). In Mini Study 1 we used the projective version of SWAT (PROSWAT). In this study we will be using PROSWAT and SWAT to rate both projected workload and the workload that you actually experienced during a simulation run.

The same rating scale is used for SWAT and PROSWAT. Workload on this scale is defined in terms of a combination of three different dimensions that contribute to the subjective feeling of "workload hard." A workload rating in SWAT is accomplished by selecting a 1, 2, or 3, on EACH of the three scales representing the dimensions of TIME LOAD, MENTAL EFFORT, and PSYCHOLOGICAL STRESS LOAD.

Each of these dimensions and their levels are described below:

TIME LOAD. Time load refers to the fraction of the total time that you are busy. When Time Load is low, sufficient time is available to complete all of your mental work with some time to spare. As Time Load increases, spare time drops out and some aspects of performance overlap and interrupt one another. This overlap and interruption can come from performing more than one task or from different aspects of performing the same task. At high levels of Time Load, several aspects of performance often occur simultaneously, you are busy, and interruptions are very frequent.

Time Load may be rated on the 3-point scale below:

1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2. Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

MENTAL EFFORT LOAD. As described above, Time Load refers to the amount of time one has available to perform a task or tasks. In contrast, Mental Effort Load is an index of the amount of attention or mental effort required by a task regardless of the number of tasks to be performed or any time limitations. When Mental Effort Load is low, the concentration and attention required by a task is minimal and performance is nearly automatic. As the demand for mental effort increases due to task complexity of the amount of information which must be dealt with in order to perform adequately, the degree of concentration and attention required increases. High Mental Effort Load demands total attention or concentration due to task complexity or the amount of information that must be processed.

Mental Effort Load may be rated using the 3-point scale below:

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.

2. Moderate conscious mental effort or concentration required. Complexity and activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD. Psychological Stress Load refers to the contribution to total workload of any conditions that produce anxiety, frustration, or confusion while performing a task or tasks. At low levels of stress, one feels relatively relaxed. As stress increases, confusion, anxiety, or frustration increase and greater concentration and determination are required to maintain control of the situation.

Psychological Stress Load may be rated on the 3-point scale below:

1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.

2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.

3. High to very low intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Each of the three dimensions just described contribute to workload during performance of a task or a group of tasks. Note that although all three factors may be correlated, they need not be. For example, one can have many tasks to perform in the time available (high Time Load), but the tasks may require little concentration (low Mental Effort). Likewise, one can be anxious and frustrated (high Stress Load) and have plenty of spare time between relatively simple tasks. Since the three dimensions contributing to workload are not necessarily correlated, please treat each dimension individually and give independent assessments of Time Load, Mental Effort Load, and Psychological Stress Load.

As noted earlier, we will be using the scale described above to make both SWAT and PROSWAT ratings. We will ask you to give us a SWAT rating after each simulation run. The purpose of this rating will be to estimate the actual overall workload that you experienced while controlling air traffic in the test scenario. Thus, your SWAT ratings will be based on specific levels of TIME, EFFORT, and STRESS load that you directly encountered while completing all of your ATC tasks. By collecting these ratings we will be able to compare the workload of the baseline/current system run with those experienced as different numbers of Data Link services are introduced.

We will also ask for PROSWAT ratings after two of the test runs. The PROSWAT ratings will refer to the specific Data Link services introduced during the test run (altitude assignment and transfer of communication in in case 2 and menu text/free text in case 3). In these situations we would like you to projectively rate the workload that you would experience

during a moderately busy shift of work using the specific service implementation presented during the test run. The purpose of these separate PROSWAT ratings will be to assess the way in which each set of service procedures impacts controller workload.

Remember, try to keep these two workload ratings as independent as possible. In the case of SWAT ratings, we want you to make a workload judgement with respect to the overall actual loading that you experienced while performing in the test scenario. For PROSWAT ratings, we want you to evaluate the projected impact of specific service implementations on controller workload during a normal work day.

Samples of the overall SWAT and PROSWAT rating forms are shown in figures B-3 and B-4.

CARD SORTS. Because each of you has already done a SWAT card sort, you will not be required to complete the scale development process a second time. If you would like to review the sort that you submitted during the last study, please see Dr. Shingledecker before we begin the test runs.

RESULTS

SWAT/PROSWAT SCALE DEVELOPMENT.

As noted above, the eight controllers who served as subjects in this study had previously completed the card sorting task during the first Mini Study. However, since one of the subjects acted only as an observer in the first study, his sort data were not included in the original scale development computations. As a consequence, new SWAT scales were computed for the present study.

Computer analysis of the card sorts revealed only moderate agreement among card orderings (W=.73). In SWAT, such a result makes it undesirable to use a single scale solution for all subjects in a sample. Therefore, the SWAT prototyping algorithms were employed to identify subgroups of subjects who produced similar card sorts. This algorithm classified three subject sorts in the time prototype, one in the effort prototype, and four in the stress prototype. Classification within a prototype group indicates that the subject weighed the associated factor more strongly than the others when performing the sort.

Analysis of the agreement among subjects within the subgroups containing greater than one case showed that both were acceptable (time, W=.90; stress, W=.88). Therefore, separate scaling solutions were computed for the three prototypes using the SWAT conjoint measurement and scaling programs. The resulting tables relating time, effort and stress ratings to interval scale values were used to score SWAT and PROSWAT ratings of individual subjects classified in those groups. Table B-2 presents the card orderings for each subject along with the mapping of scale values assigned to the prototype groups.

SUBJECT ---------------------------------------

SECTOR ----------------------------------

TEST CASE ---------------------------------------

Rate the workload that you actually experienced while controlling air traffic during this test run by placing an "X" below one of the numbers on the TIME, EFFORT and STRESS scales.

	1	2	3
TIME LOAD	-------	-------	-------
MENTAL EFFORT	-------	-------	-------
STRESS	-------	-------	-------

COMMENTS:

FIGURE B-3. OVERALL SWAT WORKLOAD

SUBJECT ----------------------------------

SECTOR ----------------------------------

TEST CASE ----------------------------------

Rate the workload associated with the services you have just examined by considering how they would affect the difficulty of your job during a moderately busy work day. With this in mind, rate the *projected* workload for each service by placing an "X" below one of the numbers on the TIME, EFFORT, and STRESS scales.

REMEMBER, these are projected workload ratings of each service as implemented for this study. Workload is not necessarily related to your preferences or the suitability of a service for use in ATC operations.

ALTITUDE ASSIGNMENT/CONFIRMATION

	1	2	3
TIME LOAD	-------	-------	-------
MENTAL EFFORT	-------	-------	-------
STRESS	-------	-------	-------

TRANSFER OF COMMUNICATION

	1	2	3
TIME LOAD	-------	-------	-------
MENTAL EFFORT	-------	-------	-------
STRESS	-------	-------	-------

FIGURE B-4. PROSWAT WORKLOAD PROJECTED

TABLE B-2. PROSWAT CARD SORTS AND PROTOTYPE SCALE VALUES

Card T	Card E	Card S	Subject Sort 1	Subject Sort 2	Subject Sort 3		Time Proto Scale	Subject Sort 8		Effort Proto. Scale	Subject Sort 4	Subject Sort 5	Subject Sort 6	Subject Sort 7		Stress Proto. Scale
1	1	1	1	1	1	-	0.0	1	-	0.0	1	1	1	1	-	0.0
1	1	2	2	2	4	-	8.7	2	-	3.8	11	8	7	2	-	29.5
1	1	3	11	3	5	-	23.4	3	-	7.7	21	17	16	5	-	54.7
1	2	1	5	4	2	-	11.3	10	-	34.6	4	3	5	6	-	13.5
1	2	2	7	6	10	-	19.9	11	-	38.5	13	14	14	14	-	43.0
1	2	3	8	7	11	-	34.6	12	-	42.3	23	22	18	15	-	68.2
1	3	1	6	5	6	-	21.7	19	-	69.2	8	5	6	7	-	23.3
1	3	2	9	8	12	-	30.4	20	-	73.1	16	16	17	16	-	52.8
1	3	3	14	9	22	-	45.1	21	-	76.9	24	25	20	17	-	78.0
2	1	1	3	10	3	-	23.7	4	-	11.5	2	2	2	3	-	10.9
2	1	2	4	11	9	-	32.4	5	-	15.4	10	9	12	4	-	40.5
2	1	3	16	14	14	-	47.1	6	-	19.2	20	18	13	12	-	65.6
2	2	1	12	12	7	-	35.0	13	-	46.2	5	4	3	8	-	24.4
2	2	2	15	15	13	-	43.7	14	-	50.0	14	10	15	21	-	54.0
2	2	3	19	16	23	-	58.4	15	-	53.8	18	23	26	24	-	79.1
2	3	1	13	13	8	-	45.5	22	-	80.8	6	12	8	19	-	34.2
2	3	2	10	17	21	-	54.1	23	-	84.6	15	20	24	20	-	63.7
2	3	3	25	18	25	-	68.8	24	-	88.5	26	26	21	25	-	88.9
3	1	1	20	19	15	-	54.9	7	-	23.1	3	6	4	10	-	22.0
3	1	2	21	20	18	-	63.6	8	-	26.9	12	11	11	9	-	51.6
3	1	3	22	21	20	-	78.3	9	-	30.8	22	19	25	23	-	76.7
3	2	1	17	22	16	-	66.1	16	-	57.7	7	7	10	13	-	35.5
3	2	2	24	23	19	-	74.8	17	-	61.5	19	15	22	18	-	65.1
3	2	3	23	24	26	-	89.5	18	-	65.4	25	24	23	26	-	90.2
3	3	1	18	25	17	-	76.6	25	-	92.3	9	13	9	11	-	45.3
3	3	2	26	26	24	-	85.3	26	-	96.2	17	21	19	22	-	74.9
3	3	3	27	27	27	-	100.0	27	-	100.0	27	27	27	27	-	0.0

The statistical analyses on workload data which are presented in the following sections were performed on SWAT and PROSWAT scores transformed from the ordinal ratings using the prototype scaling solution identified for each subject. In each case, one to three ratings on the three dimensions were interpreted by referring to the appropriate subgroup scale which ranged from 0 (low workload) to 100 (high workload). Raw score results of all workload and preference measurements obtained taken during this study are presented in table B-3.

PREFERENCE RATINGS OF WILCO PERSISTENCE TIMES.

A secondary objective of Part One of this Mini Study was to identify an appropriate duration for the display of confirmatory pilot responses to Data Link messages. The results of the first Mini Study indicated that items on the Data Link transaction list display should be automatically deleted upon receipt of a pilot WILCO downlink. However, the results did not indicate whether the display should be deleted immediately upon receipt of the response, or should remain available for inspection for a brief period of time. In order to address this issue, the menu text and free text exercises in Part One were conducted with both 0- and 12-second WILCO display persistence times. All controllers completed a preference/acceptability scale for each of the conditions.

Comparison of preference ratings for the two persistence times yielded equivocal results. The median preference rating for the immediate display deletion was 3.5 on the 1 (highly preferred) to 7 (acceptable but not preferred) scale. The median rating for the 12-second persistence was 4.5. The apparent difference was not statistically significant ($T=14$, $p=.58$). Examination of individual ratings showed that four of the subjects rated the 0-second delay more preferable, while the remaining four subjects rated the 12-second delay more preferable.

Group discussions held with the subject controllers at the conclusion of Part One of the Mini Study indicated that two conflicting factors were responsible for the split ratings. Those subjects preferring the immediate deletion of transaction data felt that long persistence times would increase display clutter and make the process of monitoring ongoing transactions more difficult. Conversely, the subjects preferring the 12-second persistence indicated that immediate removal of a transaction line could cause confusion if the controller is not monitoring the display at the point in time when the WILCO is received.

Since neither option was rated unacceptable by any of the controllers and both explanations had apparent merit, it was decided that Part Two testing would be conducted with a compromise, 6-second display persistence time. Final group discussions which followed Part Two testing indicated that this option provided an acceptable alternative which minimized the problems associated with the original persistence times.

WORKLOAD AND DATA LINK USAGE DURING THE FORMAL TEST RUNS.

As described previously in this appendix, Part Two testing consisted of five formal data collection runs for each subject during which various

TABLE B-3. RAW WORKLOAD AND PREFERENCE DATA

SWAT

		Condition				
		1	2	3	4	5
Subject	1	0	11.3	45.5	11.3	74.8
	2	54.9	11.3	11.3	11.3	11.3
	3	35.0	54.1	35.0	35.0	19.9
	4	0	0	0	0	0
	5	0	13.5	0	13.5	10.9
	6	0	0	0	0	35.5
	7	0	0	24.4	24.4	24.4
	8	0	0	50.0	50.0	34.6

PROSWAT

		AA	TOC	MT	FT
Subject	1	11.3	11.3	85.3	30.1*
	2	19.9	0	11.3	54.9
	3	54.1	11.3	11.3	43.7
	4	0	0	0	0
	5	63.7	0	54.0	22.0
	6	54.0	0	0	24.4
	7	0	0	54.0	65.1
	8	38.5	0	50.0	0

PREFERENCE

		WILCO "0"	WILCO "12"	AA	TOC	MT	FT
Subject	1	2	6	2	2	2	3
	2	5	2	2	2	1	4
	3	6	1	2	2	1	2
	4	1	7	3.7*	1.7*	1	1
	5	3	6	6	2	2	4
	6	4	3	u	1	4	4
	7	1	7	2	1	2	2
	8	6	2	4	2	4	3

* Estimated

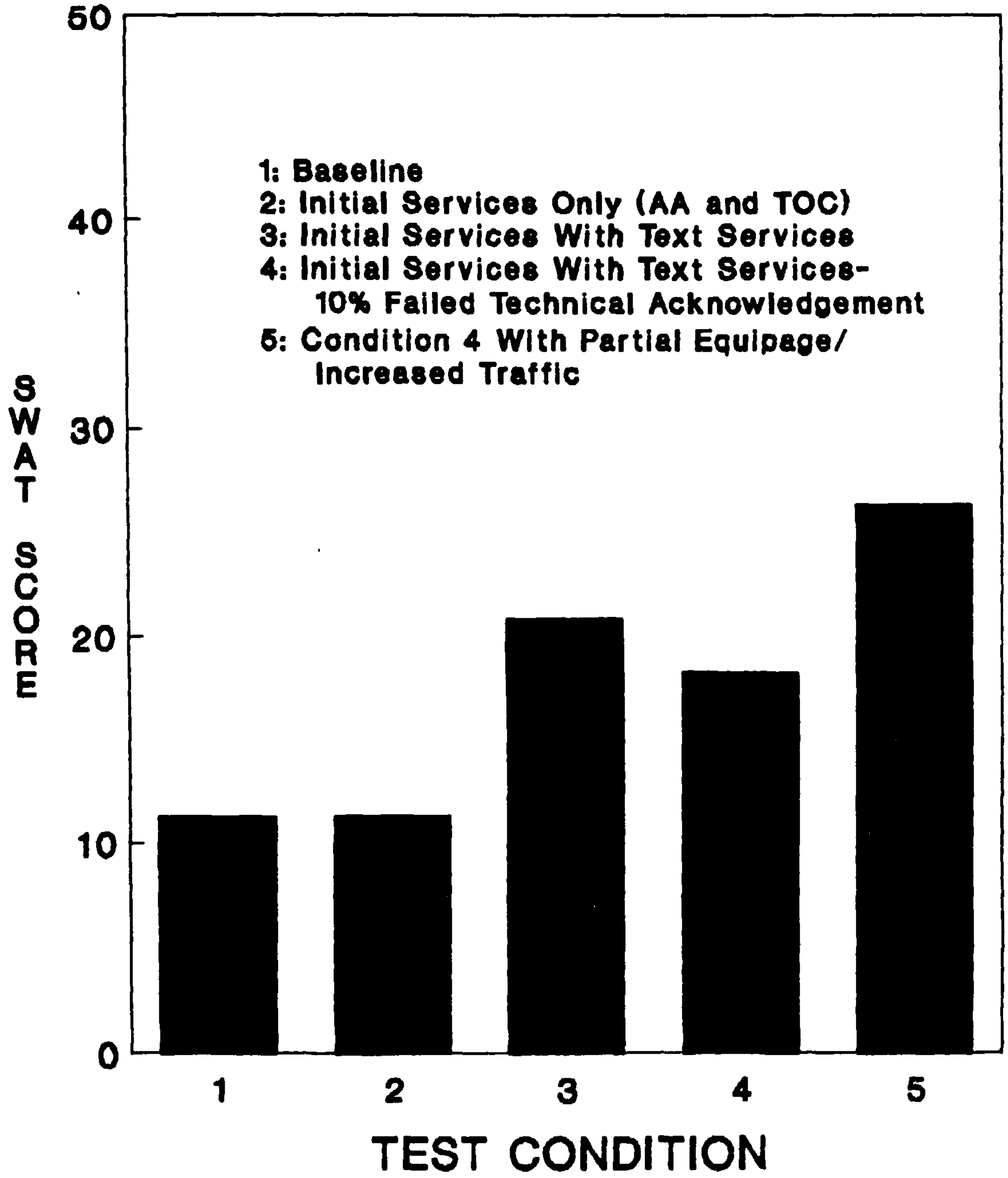
subjective and objective measurements were taken. Unlike the first Mini Study, in which only minimal air traffic was simulated for evaluating basic Data Link display and procedural design options, this study utilized a more complex scenario which presented the subjects with an actual ATC problem. One goal of this simulation was to examine the way in which controller workload, Data Link usage, and voice communications would vary under different testing conditions within the scenario.

Figure B-5 presents the mean SWAT workload scores obtained for each of the five test runs. As noted earlier, these scores reflect the actual workload experienced by the subjects during the test runs. An overall analysis of variance performed on these scores revealed no significant differences in perceived workload among the test conditions ($F=1.04$, df 4,28, $p=.4$). This result indicates that, for the test scenario used in this study, neither of the nominal Data Link conditions (2 and 3 in figure B-5) produced a significant increase in workload over the current system without Data Link. In addition, no adverse effects on workload were detected for the Data Link conditions which contained technical acknowledgement failures and mixed equipage (4 and 5 in figure B-5).

Although none of the tested conditions produced significant differences in workload, inspection of figure B-5 suggests a trend for workload to increase in the conditions in which all four services were available in comparison to the baseline conditions and the condition in which only altitude assignment transfer of communication Data Link services were available. A possible explanation for this trend can be derived from the record of Data Link transactions in each of the test conditions presented in figure B-6. This figure shows the mean number of uplinks per controller for each of the services across the test conditions. The final condition in which the number of controlled aircraft was increased is not shown since the increased number of ATC instructions required, and partial equipage, made this condition incomparable with the other test runs.

As shown in figure B-6, usage of the transfer of communication service was relatively consistent across the test conditions. However, the altitude assignment service usage dropped an average of 39 percent from the two service conditions to the conditions in which the text services were available. This result was attributable to the fact that when menu text was available to the subjects, they employed it to make a number of repetitive altitude assignments. While this capability normally would reduce controller workload, in the service implementations prepared for this study a menu text uplink did not update the NAS data base. Hence, the controllers were required to make additional data entries under these conditions to comply with requirements to maintain the currency of the data base and to maintain the accuracy of the assigned altitude data in the Full Data Block display.

This additional activity is likely to have produced an increase in rated workload for some subjects in the conditions where the menu text service was available, and probably accounts for the apparent, but nonsignificant, trend in the data.



*Workload *actually* experienced in test

FIGURE B-5. SWAT WORKLOAD*

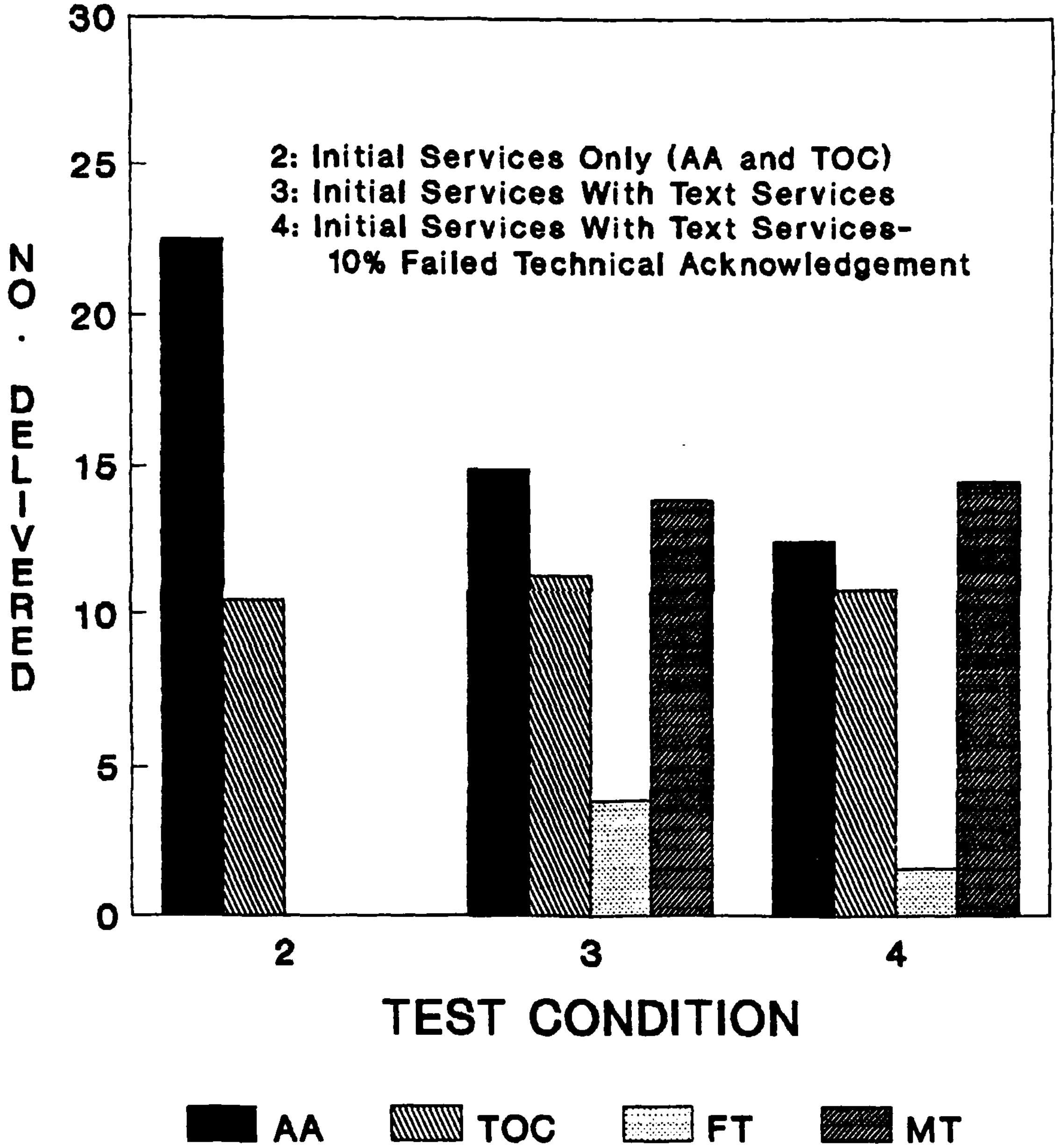


FIGURE B-6. DATA LINK SERVICES DELIVERED: SECTOR AVERAGES

PROSWAT AND PREFERENCE RATINGS OF SERVICE IMPLEMENTATIONS.

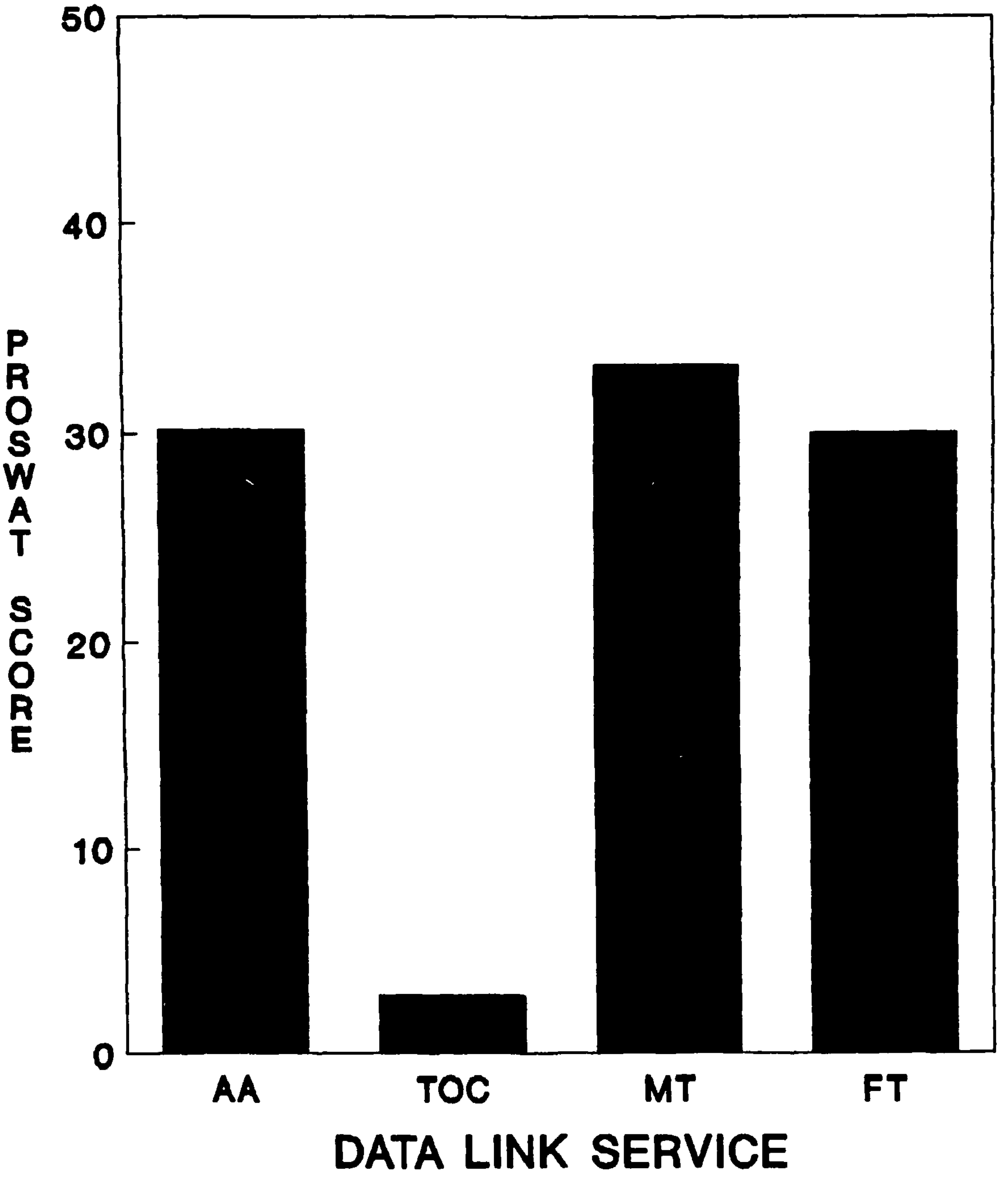
One of the major objectives of the formal data collection runs conducted in Part Two of this study was to obtain an evaluation of the specific procedural implementations of each of the services included in the initial Data Link package. In the case of the text services, this study presented the first opportunity to gather controller estimates of acceptability, preference and potential workload impact in the ATC system. While the altitude assignment and transfer of communication services had been reviewed in the first Mini Study, this study provided an opportunity to evaluate refined versions of the services under more realistic simulation conditions than those used in Mini Study 1.

Mean PROSWAT ratings for each of the four services are shown in figure B-7. As noted previously in this appendix, PROSWAT ratings indicate the estimated impact on workload in actual ATC operations of each of the services as implemented for this study.

Statistical comparisons of the PROSWAT scores assigned to each service indicated that the transfer of communication service would have a smaller effect on task loading than the altitude assignment service ($t(7)=2.98$, $p=.01$), menu text ($t(7)=2.82$, $p=.02$) or free text ($t(7)=3.29$, $p=.01$).

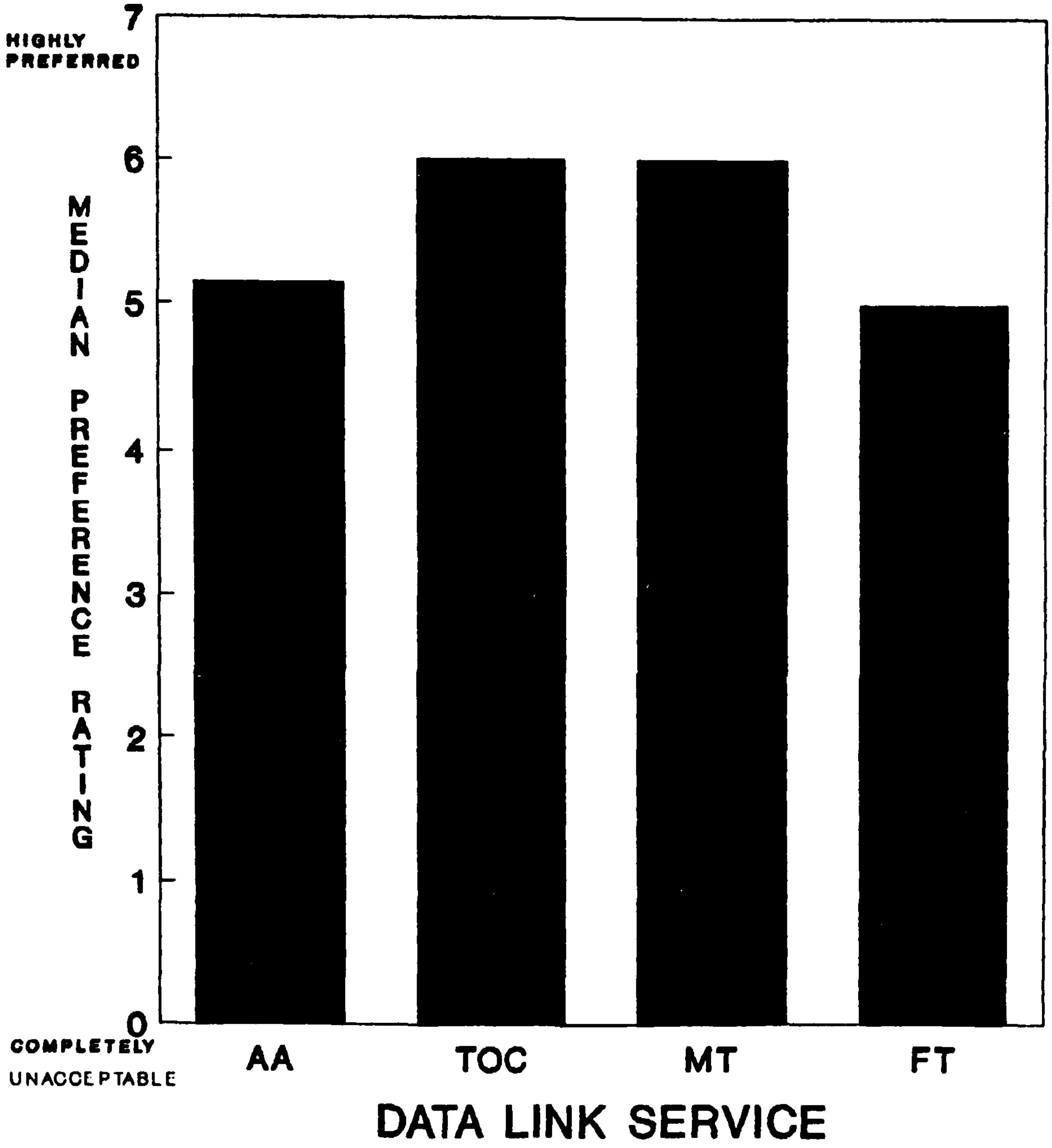
Figure B-8 presents the median preference/acceptability ratings assigned to each of the services. As the figure shows, all of the service implementations received relatively high preference scores. Only one subject assigned an unacceptable rating to any of the services (altitude assignment). Statistical comparisons among the four services also indicated that the altitude assignment service was significantly less preferred than the transfer of communication service implementation or the text services ($T=0$, $p=.01$). No other statistically significant differences in controller preference were detected.

The findings that the text services and the altitude assignment service received higher projected workload scores than transfer of communication, and that the altitude assignment service was less preferred than the other services may be attributable to several factors noted in the controller comments that were elicited on the rating forms. Based on the results of the first Mini Study, transfer of communication was implemented in a manual uplink version for this study, while altitude assignment was implemented as an automatic uplink. Controller experiences in the present study revealed that the automatic uplink would be inappropriate in situations where interim altitude assignments were required. This result reinforced comments received during Mini Study 1 which suggested that a method is needed to permit controllers to direct altitude inputs to the NAS only, to the aircraft only, or to both the NAS and the pilot. An additional factor which may have reduced preference and increased projected workload for the altitude assignment service was the difficulty encountered in monitoring the Data Link transaction list. As suggested during the first Mini Study, controller comments continued to indicate that a Full Data Block display of transaction status would reduce the workload of this service.



*Projected workload in ATC system

FIGURE B-7. PROSWAT WORKLOAD*



*Ratings for Mini Study 2 Versions of Each Service

FIGURE B-8. CONTROLLER PREFERENCE*

Workload and preference factors noted in controller comments regarding the text services included the inability to automatically update the NAS computer with a menu text uplink. The subjects who commented on this problem indicated that if text services are to be used for positive control instructions, the option should be available to transmit the data to the ATC system automatically without further keyboard inputs.

APPENDIX C

ANALYSIS OF WRAP-UP QUESTIONNAIRE DATA

TABLE OF CONTENTS

DESCRIPTION

A Wrap-Up Questionnaire was given to the Fort Worth Center controllers during the debriefing on Thursday, September 30, 1988. A copy of the questionnaire is contained herein. This report documents the statistical treatment and results.

The questionnaire was comprised mainly of 7-level rating scales and free narrative comment questions. The numerical values and verbal labels attached to the 7-level rating scale questions were:

7 = Very Good
6 = Good
5 = Slightly Good
4 = Fair (center scale)
3 = Slightly Poor
2 = Poor
1 = Very Poor

These values were used for the computation of the rating scale statistical results. Narrative comments for all questions were compiled and attached herein. Also, a frequency count of controllers making similar statements is attached.

RATING SCALE ANALYSIS

Table C-1 shows the resulting descriptive and inferential statistics for the 28 items rated using the 7-level rating scale. Means and variation about the means were computed for each of the items. A grand mean across subjects and items was computed for the entire questionnaire. Student's t scores were computed for the deviation of the means from center scale (4) and from the grand mean. In table C-1 the items are presented in magnitude order of t score. A 5-percent confidence interval about each item mean was also computed. Notes at the bottom of the table give a brief explanation of the meaning of the table headings.

Comparing the t score to the center scale value of 4 indicates whether that mean rating is significantly above or below it. Comparing the t score of an item to the grand mean indicates whether that item mean is significantly above or below the mean of all scores, which from table C-1 was computed to be 5.45 (between slightly good and good). The grand mean thus falls approximately in the middle of the group of items means. Ranking of the t scores relative to each other, such as in table C-1, makes comparison easier. These ranks are given in the results below.

RATING SCALE DATA RESULTS

The following results, using a 95 percent probability criterion (p=.05) for significance, were obtained for the rating scale questions. The grand means was significantly higher than center scale, indicating a positive response toward Data Link concepts in general. Of the 28 items rated, 21 were rated good (significantly higher than fair), 7 were rated fair (did not differ significantly from fair), and none were rated poor significantly

TABLE C-1. ANALYSIS OF HUMAN FACTORS QUESTIONNAIRE DATA FOR DATA LINK MINI STUDY 2 CONDUCTED 9/25-30/88

SUBJECTS									RESULTS												
1	2	3	4	5	6	7	8	9	N	MEAN	t.05	VAR	SDn-1	SE	RANGE	.05	tcs	tgm	Scs	Sgm	QUESTIONNAIRE ITEM ABBREVIATED TEXT
7	7	7	7	6	7	6	7	6	9	6.67	2.31	0.22	0.50	0.17	6.28	7.05	16.00	7.28	0.05	0.05	12f. Effect on pilot-controller communication
7	6	6	7	7	7	6	6	7	9	6.56	2.31	0.25	0.53	0.18	6.15	6.96	14.55	6.27	0.05	0.05	9c. Menu Text
7	6	6	7	6	7	6	6	7	9	6.44	2.31	0.25	0.53	0.18	6.04	6.85	13.91	5.64	0.05	0.05	7f. Using PVD for menu text
7	6	7	6	6	7	6	7	6	9	6.44	2.31	0.25	0.53	0.18	6.04	6.85	13.91	5.64	0.05	0.05	9b. Transfer of Control
7	6	6	7	6	7	6	7		8	6.50	2.37	0.25	0.53	0.19	6.05	6.95	13.23	5.53	0.05	0.05	12a. Effect on system capacity
7	6	5	6	7	7	7	6	6	9	6.33	2.31	0.44	0.71	0.24	5.79	6.88	9.90	3.37	0.05	0.05	7a. Menu text for control clearances
7	6	7	5	6	7	5	6	6	9	6.11	2.31	0.54	0.78	0.26	5.51	6.71	8.10	2.52	0.05	0.05	9a. Altitude Assignment
6	6	7	7	6	7	5	6	4	9	6.00	2.31	0.89	1.00	0.33	5.23	6.77	6.00	1.64	0.05	NA	12k. Effect on overall safety
7	5	7	7	6	7	6	7	3	9	6.11	2.31	1.65	1.36	0.45	5.06	7.16	4.64	1.44	0.05	NA	12l. Effect on overall controller workload
6	6	7	7	6	7	4	6	4	9	5.89	2.31	1.21	1.17	0.39	4.99	6.79	4.86	1.12	0.05	NA	7d. Free text for advisories
7	5	4	5	6	6	6	6	6	9	5.67	2.31	0.67	0.87	0.29	5.00	6.33	5.77	0.74	0.05	NA	1. Simulation realism
6	6	7	7	6	7	4	6	3	9	5.78	2.31	1.73	1.39	0.46	4.71	6.85	3.82	0.70	0.05	NA	12j. Effect on overall efficiency (speed)
	6	6	7	6	7	3	5	6	8	5.75	2.37	1.44	1.28	0.45	4.68	6.82	3.86	0.65	0.05	NA	7k. Equipage indicator
6	5	6	7	5	7	5	4	6	9	5.67	2.31	0.89	1.00	0.33	4.90	6.44	5.00	0.64	0.05	NA	12e. Effect on sector interphone coordination
7	4	4	6	6	7	6	5		8	5.63	2.37	1.23	1.19	0.42	4.63	6.62	3.87	0.41	0.05	NA	12b. Effect on keeping the picture
	5	6	7	5	7	4	5		7	5.57	2.45	1.10	1.13	0.43	4.52	6.62	3.67	0.27	0.05	NA	7j. Send inhibit method as tested
									240	5.45	1.96	2.09	1.45	0.09	5.27	5.65	15.55	0.00	0.05	NA	GRAND MEAN
5	5	5	6	5	7	5	5	5	9	5.44	2.31	0.47	0.73	0.24	4.89	6.00	5.96	-0.04	0.05	NA	7i. Response times from pilot as tested
7	5	4	6	5	7	5	4	4	9	5.22	2.31	1.28	1.20	0.40	4.30	6.15	3.05	-0.58	0.05	NA	12d. Effect on R-D controller coordination
7	5	5	4	5	7	4	4	4	9	5.00	2.31	1.33	1.22	0.41	4.06	5.94	2.45	-1.11	0.05	NA	9d. Free Text
	6	6	4	5		5	4	4	7	5.00	2.45	0.86	1.00	0.38	4.08	5.92	2.65	-1.20	0.05	NA	12g. Effect on A/C conflicts (system errors)
7	4	3	4	5	7	5	1	6	9	4.67	2.31	3.33	1.94	0.65	3.18	6.16	1.03	-1.22	NA	NA	12c. Effect on weather handling
4	4	6	4	5	6	3	6	6	9	4.89	2.31	1.21	1.17	0.39	3.99	5.79	2.29	-1.45	NA	NA	7h. Using WILCO - 10 second delete
1	3	2	5	5	6	7	6	2	9	4.22	2.31	4.40	2.22	0.74	2.51	5.93	0.30	-1.66	NA	NA	7g. Using WILCO - instant delete
	5	4	4	4		6	4	6	7	4.71	2.45	0.78	0.95	0.36	3.83	5.59	1.99	-2.06	NA	NA	12f. Effect on status board info handling
	5	2	5	5	7	2	4	3	8	4.13	2.37	2.61	1.73	0.61	2.68	5.57	0.20	-2.18	NA	NA	7e. Using RCRD for free text
	6	3	4	4		6	4	4	7	4.43	2.45	1.10	1.13	0.43	3.38	5.48	1.00	-2.39	NA	NA	12h. Effect on flight strip marking/handling
1	3	4	1	4	7	1	4	2	9	3.67	2.31	4.44	2.24	0.75	1.95	5.39	-0.45	-2.40	NA	-0.05	7c. Free text for control clearances
5	4	4	1	3	7	4	2	4	9	3.78	2.31	2.62	1.72	0.57	2.46	5.10	-0.39	-2.93	NA	-0.05	7b. Menu text for advisories

TABLE C-1. ANALYSIS OF HUMAN FACTORS QUESTIONNAIRE DATA FOR DATA LINK

MINI STUDY 2 CONDUCTED 9/25-30/88 (Continued)

NOTES:

N	=	Number of controllers responding to the questionnaire item.
MEAN	=	The average item rating across all the responding controllers. General meanings of scale values are: 1 - VERY POOR, 4 = FAIR, 7 = VERY GOOD.
t.05	=	Five percent significant t score levels with degrees of freedom = N-1.
VAR	=	Variance of the controllers ratings about the item's MEAN rating.
SDn-1	=	Corrected standard deviation computed from the variance.
SE	=	Standard Error of the MEAN; expected variability about the MEAN if the study was repeated several times under the same conditions.
RANGE .05	=	Five percent confidence interval centered about the MEAN within which, if the study was repeated several times, the new means should fall 95 percent of the time.
RANGE .05 left column	=	Low limit of the range. Any lower value is significantly below the MEAN.
RANGE .05 right column	=	High end of the range. Any higher value is significantly above the MEAN.
tcs, tgm	=	Two-tailed Student's t tests to determine whether the MEAN deviates significantly from (falls above or below) a criterion value.
tcs	=	t test is which the criterion value is Center Scale (FAIR = 4.0).
tgm	=	t test is which the criterion value is the Grand Mean over all items.
Scs, Sgm	=	Significance levels (p (.05) for the items' t scores. 05 = "better than" the criterion value, -.05 = "worse than" the criterion value, NA = Not signficantly different from the criterion value.

lower than fair). Considering the nature of the questionnaire items, this shows an overwhelming acceptance of the Data Link concepts evaluated.

Relating the item means to the grand mean finds seven items rated significantly higher than the grand mean. These items are listed below according to the magnitude of the tgm score. All items indicate a significantly good projected effect toward using Data Link actions in the field (first item rated highest). They are:

Rank	No.	Item (Paraphrased)
1	12f	Data Link effect on pilot-controller communication.
2	9c	Menu text (projected performance if implemented).
3	7f	Using PVD for menu text.
4	9b	Transfer of communication (projected performance if implemented).
5	12a	Projected effect on system capacity if implemented.
6	7a	Using menu text for control clearances.
7	9a	Altitude assignment (projected performance if implemented).

Two items are rated significantly below the grand mean. However, they do not significantly differ from fair on the rating scale. As listed below, the last is the least rated:

Rank	No.	Item (Paraphrased)
27	7c	Free text for control clearances.
28	7b	Menu text for advisories.

Rank ordering the t scores makes it possible to determine which items are notable as far as degree of preference. As a rough rule in table C-1, an item ranked 12 ranks from another item is significantly either lower or higher than the other item.

QUESTION BY QUESTION RESULTS

Question 1 asks for a rating of the simulation realism. The resultant mean rating is significantly better than fair. Thus, realism is judged good.

Question 2 shows suggested improvements for realism. Five suggestions are made. These are in the narrative comments section attached.

Question 3 asks if the traffic samples for the different runs were fairly equal in number and type of control events. The response is 8 yes and 0 no, indicating significant agreement.

Question 4 asks for documentation of system malfunctions Three are mentioned. These are in the narrative comments section attached.

Question 5 asks for training suggestions. Three are listed. These are found in the narrative comments section. Comments indicate that training was adequate.

Question 6 asks if the four services were used often enough to give a fair evaluation. The answer was significantly yes for each:

	Yes	No
1. Altitude assignment	9	0
2. Transfer of communications	9	0
3. Menu text	9	0
4. Free text	8	1

Question 7 rates Data Link aspects regarding possible utilization in the field. All were judged significantly good except the following which were judged fair.

Menu text for advisories
Free text for control clearances
Using RCRD for free text
Using WILCO - instant delete
Using WILCO - 10 second delete

It's significant to note that the antenna sweep delay for Data Link was judged good enough for utilization.

Question 8 asks which configuration was optimum as tested. The results were unanimous:

Current system	0
Data Link, no text	0
Data Link, menu and free text	9

Question 9 rates how well each service as presently configured would perform at position. Results show that menu text, transfer of communication, and altitude assignment were judged significantly good. Free text was judged fair.

Question 10 asks what control events are best handled by free text. The narrative answers are documented in the comments section. No majority for any one comment.

Question 11 asks what control events are best handled by menu text. The narrative answers are documented in the comments section. A majority said crossing restrictions, altitude assignments, and speed control are pertinent.

Question 12 asks for the projected effect of using Data Link with menu and free text at current position. All effects were judged significantly good except the following which were judged fair: weather handling, flight strip marking, and status board information handling. Highest rated was pilot/controller communications. Good effects were predicted for system

capacity, safety, and efficiency and controller workload. Also good effects were predicted for system errors, sector coordination, and keeping the picture.

Question 13 inquires about aural alarms and visual blinking. The narrative answers are documented in the comments section. No majority answers were given.

Question 14 inquires about gaps in the Data Link system. Narrative responses in the comment section indicate no majority response.

Question 15 asks what was liked best about Data Link. Narrative answers in the comments section indicate no majority response.

Question 16 asks what was liked least about Data Link. The answers are in the narrative comments section. No majority response.

Question 17 asks for suggestions on operational changes. Narrative answers in the comment section show no majority of response.

Question 18 asked for projected future uses of Data Link. There are many comments listed in the comment section. They are scored according to rank. No majority response.

SUMMARY OF RESULTS

The controllers reported that the Data Link Mini Study 2 had good realism, training was adequate, and malfunctions minimal. They judged that they had sufficient use of the four Data Link services to give a fair evaluation. They also judged that the control tasks per run were equal in difficulty so no imbalance in tasks affected comparison of the ATC systems evaluated.

Of the three systems tested, the controllers unanimously favored the Data Link system using menu and free text over both the current system and Data Link without text. This, despite the fact that a random 0- to 6-second antenna delay was built into the Data Link response time. The response delay itself was found good.

Of the four services tested, menu text, transfer of communications, and altitude assignment were rated significantly good. Free text was rated fair.

Menu text was found good for control clearances and fair for advisories. Free text was just the opposite. The PVD was judged good for menu text display, the RCRD fair for free text display. Interestingly, there was no significance between rating the 10-second WILCO and WILCO instant delete, which were both rated fair for utilization. The equipage symbol and method of send inhibit (using manual mode for transfer of communication) were judged good.

The projected effects of using the Data Link ATC system with menu and free text as tested were exceptionally good. Three of the 12 effects were rated fair, while 9 were rated significantly good, including system capacity and

overall safety, efficiency, and controller workload. Good effects were also projected for system errors, R and D controller coordination, and sector interphone.

Of the narrative answers in the comment section, the responses amounted to a majority for only one question; best use for menu text. A majority desired menu text for crossing restrictions, altitude assignments, and speed control. No doubt menu text, as the single highest rated of the four tested Data Link services, will remain as a permanent feature of any future Data Link design.

Future investigations as a result of these analyses should be to interpret why certain aspects elicited very diverse controller judgments--from very good to very poor. These aspects listed in table C-1 are:

Using Data Link for weather handling
Using WILCO - instant delete
Using RCRD for free text
Using menu text for advisories
Using free text for control messages.

MINI STUDY 2 CONTROLLER COMMENTS BY QUESTION

Question 1. No Comments

Question 2. How can we enhance realism?

Controller No.

2 Increase traffic load.

3 Traffic will have to be increased not only to today's levels, but increased to future levels to prove existence when put into use.

5 Traffic volume increased.

6 More complex traffic. Do not use the Dysim Lab.

7 By adding more situations requiring more controller actions (for separation).

8 Regardless of this test, it helps visualize what Data Link would be like in live heavy traffic. Realism was respectable and easy to project into real world possibilities.

9 More traffic, more complexity.

Question 3. Were the traffic samples for each run fairly equal in number and type of control events: Yes ____ No _____

If not, please indicate which runs were easier or harder because of differences in the traffic sample, not control method used.

Controller No.

7 Yes, but only in relation to each other.

9 High altitude sector needs more traffic.

Question 4. Please document any hardware or software malfunctions that working properly would have helped you make a fairer evaluation.

Controller No.

1 Temporary altitude key did not always respond the way it does in the field.

2 None.

3 Need Dysim tracks on all targets to speed updates from pilot.

5 None.

7 I am not aware of any.

8 One malfunction where an altitude assignment remained on the PVD list even when two additional altitude reassignments were given to the same aircraft. Caused questions as to which altitude was being used.

Question 5. Looking back at training, are there any new ideas as to what training would have aided you?

Controller No.

2 None.

3 No.

5 No training needed.

6 No.

7 The training was adequate, however, I would suggest sooner and more emphasis on actual "hands-on" exposure.

9 Step by step process.

Question 6. Did you use the four services in this test often enough to be able to give a fair evaluation?

Controller No.

3 Free text will probably be used only with non-comm aircraft.

8 Projecting to real world traffic, all these functions have good potential and have basics built in that can be evaluated fairly.

Question 7. Please rate these Data Link aspects regarding possibility of utilization in the field.

Controller No.

8 Menu text for control is very plausible and PVD display is the place for it. WILCO is also essential from a liability standpoint.

9 The equipage indication needs work.

Question 8. Not a narrative question.

Question 9. Please rate how well each service as presently configured would perform at your position.

Controller No.

8 Free text needs additional character space.

Question 10. What control events do you foresee would be best handled by free text instead of voice or menu text?

Controller No.

2 Radar vectors.

3 Lost comm.

6 No control functions - just non-control.

7 Unusual information, i.e., weather data, PIREPS, and perhaps radar vectors.

8 SIGMETS, airport weather sequences - not control events. Amended control events in event of a stuck microphone or blocked frequency.

9 No radio, event sensitive.

Question 11. What control events are repetitious enough to make them best candidates for menu text messages?

Controller No.

1 "Sector Specific" control acting, such as standard altitude assignments.

2 Speed control and crossing restrictions.

3 Altitude with crossing restrictions.

5 Frequency changes, altitude changes, climbing and descending crossing restrictions, altimeter settings for en route low altitude aircraft.

6 Altitude assignments, with and without crossing restrictions.

7 Altitude crossing restrictions, common speed reductions, issuance of altimeter settings.

8 Crossing fix altitudes and standard low to high altitude climb clearances (230). An occasional speed on sequencing sectors, too.

9 Crossing, speed, altitude.

Question 12. Using the four Data Link services tested, what would be the projected effect of Data Link at your position on the following: System capacity, keeping the picture, weather handling, R-D controller and sector interphone coordination, pilot-controller communications, aircraft conflicts, flight strip handling, overall efficiency (speed), overall safety, overall controller workload?

Controller No.

1 Speed and workload would be adversely affected until controller proficiency is achieved with new technology.

6 Fair comments above = no change or no effect.

8 Keeping the picture can be much improved by updating Data Link in the data block.

Question 13. How were the attention alarms? Should anything be made to blink or not blink? How about aural alarm?

Controller No.

1 Consider using intensified characters instead of blinking.

2 Blinking data blocks for failed messages - no alarm.

3 No blinking except possibly in list when clearance has not been acknowledged.

6 Keep blinking anything to a minimum. No aural alarm.

7 An aural alarm is a very good enhancement.

8 Recommend no blinking - possibly highlighting (double intensity) certain data block fields.

9 No aural alarm. Blink??

Question 14. Using Data Link should leave no "gaps" in the system. Did you see any places where gaps in positive control could occur? Also give any ideas as how to prevent them.

Controller No.

2 No.

3 Only when clearances are timely.

6 Refinements to the altitude assignment needs to be made.

8 When the data block control is given up, yet the aircraft is on another frequency - possible miscommunication on Mode S clearances.

Question 15. What about Data Link do you like best, and why?

Controller No.

1 Reduce frequency congestion.

2 Transfer of communication.

3 Ability to have two lines of communication going out.

6 Controllers could handle more aircraft. Cut down on frequency congestion, make the noncontrol messages easier to send.

7 The speed, which allows mental time for other tasks.

8 If for frequency changes alone it saves time and allows frequency time to be utilized more efficiently, whether through more information transmitted during the same time frame as previously or whatever.

9 Increased capacity. Additional comm system.

Question 16. What about Data Link do you like least, and why?

<u>Controller No.</u>

1 Less than immediate confirmation or control instructions. The heavy reliance upon data entries. No vocal/personal interaction with pilots.

2 The sense of sound is not used. The eyes take over what the ears used to do - perhaps for every entry a computer response in the ear would do better than all the symbology.

3 Too much attention taken away from watching traffic.

5 Transfer of data block or handoff carrying Data Link control instead of when transfer of frequency is changed.

7 Having to scan so many different areas on the PVD - it is difficult to maintain a mental picture.

8 PVD list is too hard to keep up with under heavy traffic - must have visual indication in the data block.

9 Time delay. Satellite coverage may be better.

Question 17. What operational changes would you like to see for:
Altitude Assignment?

<u>Controller No.</u>

2 Selective inputs (computer only, pilot only, or both).

3 Reflected in data block when input is made.

7 Response located in the data block.

8 Data block display - also updated from the menu text. If altitude is uplinked (240) have the altitude that is to change be highlighted (possibly brighter) until WILCOed then return to normal

intensity. Use this to hopefully eliminate/supplement the PVD status list for Data Link. In case of fail - that would need to be indicated in data block.

Interim Altitude:

Controller No.

2 Same as above - selective inputs - computer only, pilot only, or both.

3 No change.

7 Same as above (response located in the data block).

8 Updated on data block from the menu text. The other options for sending to various sources (i.e., pilot only, NAS only, both, etc.) is very good.

Transfer of Communication:

Controller No.

2 Eliminate ability of the receiving controller to uplink unless transfer of communication has been accomplished.

3 Indication when aircraft is on frequency.

7 None.

8 Data block displayed. Visual indication if the aircraft is on frequency. Indicate frequency change by brightening data block field until WILCO. This would eliminate PVD list. Fail would have to be indicated in data block also. Possibly have the affected portion of the data block remain normal intensity until WILCO then be highlighted.

Possibly? If time-sharing of frequency change overloads that particular portion of the data block with too much information, then perhaps altitude can be indicated in the data block and frequency can be indicated in your PVD list (not in the data block). (Prefer both in data block, however.)

Menu Text:

Controller No.

2 Increase to 30 characters.

3 No change.

7 None.

8 Update data blocks when entry is made.
Use symbols to represent certain standard phraseology.
Example: 230 = climb and maintain FL230
240 = descend and maintain FL240
250 = maintain speed of 250.

Free Text:

Controller No.

2 Unlimited characters.

3 No change.

7 None.

8 Longer format - more available characters.

Question 18. What future service would you like to see Data Link do? If more than one, rank in importance with 1 = highest.

Controller No.

Rating 1 ______________________________

2 Transfer of Communication.

3 Get more information out of cockpit.

5 Ground speed downlinked controller.

6 Radar vectors.

7 Heading assignments

8 Control instructions (All).

9 Check-in calls.

Rating 2 ________________________________

2 Altitude changes.

3 Automatic control with computer.

5 Headings.

6 Speed control.

7 Multiple speed assignments (excluding free text).

8 SIGMETS, weather sequences: previously stored that can be sent.

Rating 3 ______________________________

2 Menu text.

6 Complete non-voice system.

7 Reroute assignments.

Rating 4 ______________________________

2 Free text.

6 100% fleet Data Link equipped.

7 Weather data.

DATA LINK MINI STUDY 2
COMMENTS CATEGORIZED
(Two-Comments Minimum)

Number of Controllers Commenting	Comments
7	Menu text is best for altitude assignments.
7	Menu text is best for crossing restrictions.
6	Menu text is best for speed control.
4	Add more aircraft to traffic sample.
3	Make traffic sample more complex.
3	Free text is best for lost communications, blocked frequency or no-comm aircraft.
3	Free text is best for unusual information or events.
3	Attention taken from data block was least liked.
3	Reflect all actions in field data block.
3	Recommend no blinking or minimum blinking.
3	No aural alarm.
3	Liked best is reduced frequency congestion.
3	Headings are a good future service.
3	All instructions, complete automation, is a good future service.
2	Altimeter for low altitude aircraft is good for menu text.
2	Free text is best for noncontrol functions.
2	Free text is best for PIREPS, SIGMETS, weather reports.
2	Free text needs additional characters.
2	Free text is best for radar vectors.
2	Least liked was slow response.

Number of Controllers Commenting	Comments (Continued)
2	Least liked was loss of voice contact.
2	Liked best was another line of communication.
2	Liked best was possibility for increased capacity.
2	Consider highlighting versus blinking characters.
2	Blink data blocks for failed messages or unacknowledged clearances.
2	Possible change is selectable inputs - computer only, pilot only, or both.
2	Would like visual indication when aircraft is on frequency.
2	Possible future use - speed control.
2	Possible future use - weather.
2	Possible future use - downlink cockpit information.

Possible Future Uses

Rank		Score
1	=	4 points
2	=	3 points
3	=	2 points
4	=	1 point

Number of Controllers Responding	Comments	Score
3	Headings	11
3	All Instructions	9
2	Downlink Cockpit Information	8
2	Speed Control	6
2	Weather	4
1	Check in Calls	4
1	Transfer of Communications	4
1	Altitude Changes	3
1	Menu Text	2
1	Free Text	1
1	100% Equipage	1

APPENDIX D

DATA LINK CONTROLLER PROCEDURES

En ROUTE RADAR CONTROLLER DATA LINK CHART

1

PURPOSE	Q/A KEY	CAT Key	FUNC Key	Field Content	Comments
<u>DATALINK</u> <u>Sector Set-Up Option</u> Service Active Mode		DLC	DATALINK SETTING	1 or ON / 0 or OFF	On will appear on PVD. Off deletes the DataLink set-up indicators from PVD.
Operational Mode		DLC	DATALINK SETTING	A or M	A = Automatic / M = Manual A or M will appear on PVD.
Status List Display		DLC	DATALINK SETTING	P or C or N	P = PVD / C = R-CRD / N = *No Display Device* P or C or N will appear on PVD.
<u>SERVICE</u> <u>Altitude Confirmation</u> <u>(Automatic Mode)</u> Assigned Altitude	ASGD ALT (QZ/QT)			ddd AID	Uplink occurs upon acceptance of message. Offset Dir/Leader Length QZ, Start Track or Coast Track QT.
Interim Altitude	INTERIM ALT (QQ)			ddd AID or Rddd AID	Uplink occurs upon acceptance of message.
<u>*Altitude Confirmation</u> <u>(Manual Mode)</u> *Assigned Altitude	ASGD ALT (QZ/QT)			ddd AID	Message placed in "HELD" status upon acceptance. Offset Dir/Leader Length QZ, Start Track or Coast Track QT.
*Interim Altitude	INTERIM ALT (QQ)			ddd AID or Rddd AID	Message placed in "HELD" status upon acceptance.

*Requires Manual Uplink (See Status List)

PURPOSE	Q/A KEY	CAT Key	FUNC Key	Field Content	Comments
*Transfer of Communications Accept Handoff	(QZ / QN)			AID	Accept Handoff causes message to be placed in HELD status. The initiating controller can send, resend or delete this message.
Menu Text Uplink Build Menu Text Message		DLC	MENUBUILD	d LLL	d is reference number(0-9) for menu entry. LLL(up to 20 char.)
Send Menu Text Message		DLC		d AID or d ALL or d...d AID or d...d ALL	The ALL option sends message to all FLID under the sector control. d is reference number (0-9) for menu entry.
Delete Menu Text Message		DLC	MENUBUILD	d	d is reference number (0-9) for menu entry.
Reposition List	PVD			T TB	
Free Text Uplink		DLC		T LLL AID or T LLL ALL	LLL(up to 20 characters). The ALL option sends message to all AIDs under the sector control.

*Requires manual uplink (See Status List)

3

PURPOSE	Q/A KEY	CAT Key	FUNC Key	Field Content	Comments
EMSAW Automatic Uplink					Message sent automatically by system.
*Manual Uplink					Message placed in HELD status automatically by system.
Status List					
Send Manual Uplink				TB MSG or	
		DLC		AID (Service Type)	Service type optional (AC, TC, MT, FT, EM)
Resend Message				TB MSG or	
		DLC		AID (Service Type)	Service type optional (AC, TC, MT, FT, EM)
Delete Message				D TB MSG	
Reposition List	PVD			L TB	
Multi-Trackball Single-Trackball Use		DLC	DATALINK MLT TB(F2)	TB MSG ENTER (KB)	KB = Keyboard device.
Multi-Trackball Use		DLC	DATALINK MLT TB(F2)	TB MSG ENTER (KB)	Up to 4 messages can be trackballed.

*Requires manual uplink (See Status List)

Field Name	Format	Comments
AID (02)	La (a)(a)(a)(a)(a) dda, dddd; trackball	
Assigned Alt (08)	ddd	
List Display	L, T	Status, Menu Text
Ident (61)		
Interim Altitude	ddd or Rddd or T	

Field Name	Format	Comments
Trackball (65)	TB	
Service Type Ident	AC, TC, MT, FT EM	Alt. Confirmation, Transfer of Comm, Menu Text Uplink, Free Text Uplink, EMSAW.
Text	T	Up to 20 characters.
FLID	L a(a)(a)(a)(a)(a)	
Data Link Equipage Indicator	◇	Symbol appears in data block next to FLID.

DATA LINK STATUS LIST FORMAT

Examples

. UAL1234 TC 23.450 WIL

TB POINT FLID Service Type Data Area Status Indicator

.TWA2579 AC 270 DLV
.DAL1680 MT X STON SNT
.BAL8048 FT CALL C NAK

Where:

TB Point = Designated area to Trackball.
FLID = Aircraft Identification or Call Sign (up to 7 characters).
Service Type = A particular data link service (AC=Alt. Confirmation, TC=Transfer of Comm, MT=Menu Text Uplink, FT=Free Text Uplink, EM=EMSAW).
Data Area = An area that provides the AT instructions/command sent to pilot (up to 6 characters).
Status Indicator = Current status of message (SNT=SENT, DLV=DELIVERED, WIL=WILCO, HLD=HELD, NAK=No Acknowlegment, UNA=UNABLE, TIM=TIMEOUT).